

Gable End Bracing

Retrofitting Gable Ends to Improve their Resistance to Hurricanes

The following prescriptive methods are intended for applications where the gable end wall framing is provided by a wood gable end wall truss or a conventionally framed rafter system. The retrofits are appropriate for wall studs oriented with their broad face parallel to or perpendicular to the gable end surface. Gable ends to be strengthened shall be permitted to be retrofitted using methods prescribed by provisions of this section. These prescriptive methods of retrofitting are intended to increase the resistance of existing gable end construction for out-of-plane wind loads resulting from high wind events. The retrofit method addresses four issues by strengthening the framing members of the gable end itself with the use of retrofit studs, bracing the top and bottom of the gable end so that lateral loads are transmitted into the roof and ceiling diaphragms by the use of horizontal braces making connections between horizontal braces and retrofit studs by the use of straps and connecting the bottom of the gable end to the wall below to help brace the top of that wall by the use of right angle brackets. The minimum ceiling diaphragm shall be comprised of minimum ½" thick drywall, plywood a minimum 3/8" thick nailed a maximum of 12" on center on both edges and intermediate locations, or plaster installed over wood lath.



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1.0 Introduction

Gable ends are the upper triangular walls that rest on rectangular walls. The triangles may be of various proportions and may have a section cutoff. The Figures 1 through 6 show a variety of gable ends. The only gable ends for which retrofitting is addressed in this guide are those that have attic space for working. It does not address gable end walls where the room behind the wall has a cathedral or vaulted ceiling. Gable ends with attics that have headroom greater than 3' are the ones that typically need to be retrofitted.



Figure 1. House with large and small gable ends



Figure 2. Large gable at end with partially exposed gable where house is wider



Figure 3. Gable end with attached chimney



Figure 4. Cut off gable over garage with covered entry to side



Figure 5. Gable end with intersecting shed roof

Figure 6. Gable end over garage and living area

Wind Forces on Gable Ends: Many people think of hurricane winds as pushing against buildings; inward. However, hurricanes both push (inward) and pull (outward) on houses when wind pressures are applied to the house. In fact, the outward acting, negative pressures are higher than inward acting, positive pressures. Additionally, the outward acting (negative pressures) that causes uplift on roofs can be much larger than the inward or downward pressures on the roof. Because hurricanes are large powerful storms, a house near the track of the storm may experience strong winds from several different directions. It is hard to know which gable end will experience the highest wind pressures and whether the pressures will be inward or outward acting. Consequently, it is prudent to retrofit the largest gable ends first and then work the smaller ones with the intent of doing them all.

Typical Traditional Construction Practices: Because of a lack of understanding of outward and inward acting wind pressures on gable ends, older building codes did not pay as much attention to holding gable end walls onto buildings as they do now. Gable end walls were not necessarily built to withstand the pressures that hurricanes can impose. In fact, before air conditioning, a key comfort in houses was ventilation and in particular attic ventilation. Attics with lots of ventilation were valued because they kept houses cooler. Sometimes gable ends were built to allow cooling of the attic space and consequently they did not have structural wall sheathing. Instead, they had siding boards with horizontal gaps below each board or large louvered gable end vents to facilitate the flow of air while shedding rain.

The impression that nothing could be done to strengthen gable ends further compounded the problem. However, knowledge of weather, progress in building science, and engineering analysis and research has significantly improved our knowledge on gable end construction. Building codes have been changed to require stronger connections between the parts of the house. Building codes are also being better understood, more carefully read, and better enforced. Consequently, buildings are being better built.

Types of Failures: Basically, there are three things to be concerned about with gable end walls. First, the most common type of failure is loss of roof sheathing from the gable end that results in the gable wall losing its bracing along the top edge. This type of failure is shown in Figure 7. When winds blow against the gable end, they push it towards the interior of the house and push up on the roof overhanging the gable end. At the same time the wind flowing over the top of the roof creates large negative pressures (uplift) on the roof sheathing. This combination of loads led to widespread loss of roof sheathing at gable ends and gable end failures in numerous hurricanes and has been frequently observed for older homes.

The second most common type of gable end failure is at the connection where the gable section meets the wall below. It is rare that you actually find a failure that looks like the one shown in Figure 8; because, usually the wall below fails and the whole end collapses as shown in Figure 9. The third weak link is the actual framing members that make up the gable end wall structure. In many houses, these members are the structural members of the end roof truss. Consequently, the 2x4 lumber members are bent by wind forces applied to the wide-flat-part of the 2x4s – the direction in which they are the weakest. In homes with conventional framing (rafters and ceiling joists), the wall structure will typically be made of 2x4s turned so that wind forces are applied to the narrow face of the 2x4s (the orientation with the strongest resistance to bending of the 2x4s) but they may only be just toe-nailed to the rafters and ceiling joist thus providing inadequate connections.



Figure 7. The most common gable end failure is one where the wall loses support along its top edge because sheathing is blown off. The wall may fold outward (see cover picture) or be blown inward.



Figure 8. The second most common type of gable end failure is at the connection between the rectangular and triangular walls – Here the failure is just starting.



Figure 9. The most common result of wall connection failures is a missing gable end wall and the wall below.

When is it Important? The taller the gable end triangle, the greater the risk of damage in a hurricane. For gable ends that are less than 4-feet tall (those with about 3-feet of head room in the attic and gable end wall framing members that are 3-feet or shorter), the forces applied by a 140 mph wind gust along the top and bottom edges of the gable end wall will be less than 100 pounds per foot of gable width. Most nailed connections will withstand these forces. In addition, if the gable end is less than about 4-feet tall, it will be difficult for a worker to access the gable end to perform the necessary retrofit work from inside the attic.

In homes built in areas where the high wind requirements of the Standard Building Code were being enforced, you may find the gable end wall has already been braced or was built in a way that is strong enough to not need bracing. In some of these homes, the wall studs may continue without a break from the floor below all the way up to the roof. This type of framing is known as balloon framing and is one of the best ways to make a very strong gable end wall. You will be able to recognize balloon framing if you don't see any joints between the gable end wall studs and the wall below. If you see any horizontal plates at the ceiling level where the studs stop and are fastened to the plate, you do not have balloon framing. The masonry alternative to balloon framing is to continue the masonry wall all the way up to the roof and to install reinforcing in the wall that extends throughout the height of the wall and has a solid rake beam with solid filled or grouted cells. If you find this situation, you will not see a wood frame wall at the gable end.

Gable Ends Not Covered in Guide: Gable end walls on rooms with vaulted or cathedral ceilings pose special problems for retrofitting. Unless care was taken in the design and construction of these walls to provide the kind of bracing they need to stand up to strong winds, they are very likely to fail. The structural solutions usually involve beams that either span across the width of the wall or columns that span from floor to ceiling. In many cases, when the wall was originally constructed, the builder could have used continuous members that run from the floor to the ceiling and avoided the weakness. If you have a conventionally framed gable end wall on a room with a cathedral ceiling, you may be able to push on the wall and see it deflect (move). If so and you want to strengthen the wall, you need to hire a structural engineer to develop a good structural solution for your particular situation.

2.0 Overview of the Retrofit Process

From the discussion in the introduction, you should realize that making sure the roof sheathing stays attached to the roof structure is a very important part of a comprehensive approach to reducing damage at gable ends. If you have re-roofed your house and had the roof sheathing re-nailed to the latest code requirements or following the recommendations in the retrofit guide, you have gone a long way towards reducing the likelihood that your gable end will fail. However, bracing of gable ends is also very important for larger gable ends and this guide focuses on ways to accomplish that bracing. If you have not had your roof deck re-nailed, you can finish off the bracing job by applying beads of AFG-01 rated structural wood adhesive (many sub-floor adhesives available in caulking tubes at home improvement stores carry the AFG-01 rating) along the joints between the roof sheathing and the roof framing members using directions provided in the web based retrofit guide.

Retrofitting gable ends to brace the walls entails **two specific activities**.

1. **Strengthening and bracing the gable end** which involves making the triangular shape end wall stronger and anchoring this wall to the roof and ceiling structure.
2. **Strengthening the wall-to-wall connection** which involves connecting the gable end wall to the exterior wall below.

Determining which of these steps should be done first depends on the types of walls and the method used to connect the walls. If the gable end wall is a conventionally framed wall and the wall studs are just toe-nailed in place, then you should install straps or right angle brackets to anchor each of the studs longer than 3' to the upper and lower framing members. If you attach the studs to the top and bottom plates using brackets that have to be nailed to the edge of the top and bottom plates, they must be installed before the horizontal braces are installed. Figures 12 and 13 provide examples of typical combinations of gable end wall framing with variations of framing below. They also illustrate some of the typical bracket installations that can be made to anchor the walls together.

Strengthening and bracing the gable end: Figure 10 illustrates the components involved in strengthening a gable end wall and **Section 9** provides detailed construction instructions. Figure 11 is a photograph of a completed gable end retrofit taken from an angle that is similar to that in Figure 10. The first step in strengthening and bracing the gable end is to install 2x4 braces that butt up against the gable end that extend at least 6' into the interior of the attic. These 2x4s, called Horizontal Braces, distribute (share) the wind loads applied to the gable end wall with a larger area of the roof structure so that the house can better absorb the forces applied to the gable end. It is easy to sense that the plane of the roof is strong if the roof sheathing stays in place.

But it is less obvious that the ceiling plane of the living space, i.e. drywall or plaster ceilings is also good at resisting forces applied to the gable end as long as they can be applied over a relatively large area. The horizontal braces are used to transfer the wind forces applied to the gable end into the roof and ceiling and to distribute these forces over a large enough area to avoid local failures of the roof sheathing, ceiling drywall or plaster.

Because existing gable end studs are usually not strong enough, the next step in strengthening and bracing the gable end is to attach new studs, here called Retrofit Studs, next to the studs already in the gable end wall. The final step in strengthening and bracing the gable end is to connect the retrofit studs to the horizontal braces by using straps and Compression Blocks. With the completion of these steps, the wall itself is strengthened and tied into the roof structure so that it acts as a much stronger unit.

Strengthening the wall-to-wall connection: This activity simply connects the wall below to the reinforced gable end wall and involves installing straps, brackets, or screws between them to make a strong connection. A good connection between a strengthened gable end wall above and the wall below will do a great deal to help strengthen the lower wall by restraining the top of it from moving in or out. This will make the whole end wall of your house much stronger and better able to resist wind loads. Usually making a good connection is relatively easy once one decides on the appropriate method to be used. You will need to look at the construction details of the top of the lower wall and of the bottom of the gable end wall to determine which of the methods suggested here should be used to strengthen the connection. Section 10 provides detailed construction instructions for strengthening the wall-to-wall connections.

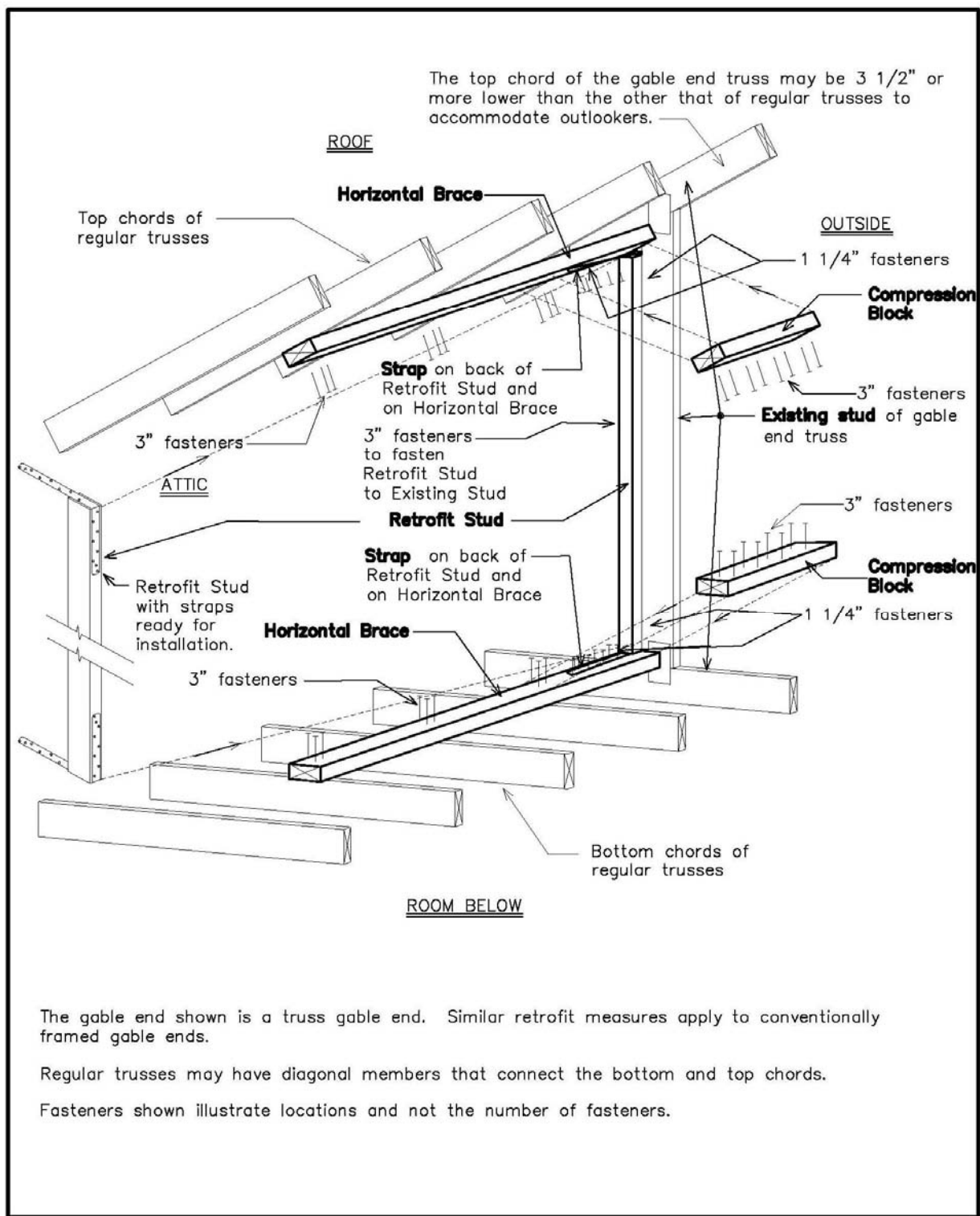


Figure 10. Overall sketch showing the concept for strengthening and bracing a gable end wall



Figure 11. Photograph of completed gable end retrofit – the light colored wood is the lumber added during the retrofit activity

When to do retrofit work: In the summer on a day that is very sunny at all, it is likely that one can work in attic only until about 10 a.m. when temperatures can be expected to be in the high eighties to mid nineties or even higher. Those temperatures may not seem high, but working in those conditions for very long take a toll on ones strength. If one is cool and fresh and then enters an attic at 11 or 12 one might suppose that one could work quite a while, but it does not take very long to become overwhelmed by the oppressive heat. At 3:30 in the summer one can expect temperatures to be in the 125 degree range. This points to the need for planning to get work done early in the day or for working in cooler seasons. However, even in spring and fall, attics can be oppressively hot in the afternoon. For homeowners doing retrofit work it is not impractical and maybe even desirable to work just a few hours every day or on weekends. For contractors this kind of schedule is inefficient unless there is other work outside an attic that can

be performed the rest of the day. If workers stay in an attic too long they exhausted for the rest of the day unless it is in an air conditioned area and they are properly hydrated.

3.0 Collecting information on wind exposure and risk

In order to plan the gable end retrofit, you will need two essential pieces of information. These are the Exposure Categories for the house and the Basic Design Wind Speed for your house's location. This information was used by engineers to determine how strong the various retrofit components need to be and is required to extract the correct information from Tables 1 and 2. Consequently, you will need to learn both the Exposure Category and the Basic Design Wind Speed of the house to use these tables.

The exposure category tells engineers how vulnerable the house is to wind based on its location. For example, as you might expect, a building nestled in a treed area or in an area surrounded by a lot of other houses would be exposed to wind that has been broken up (attenuated) by those features compared to a building that faces a large body of water, a wide golf fairway, or sits atop a prominence. Because the difference in location can have a rather dramatic affect on expected wind speed the exposure category is an important factor in determining risk and retrofit measures that need to be taken. Look at the area surrounding the house. If you live in the middle of a subdivision, at the edge of a subdivision but are surrounded by trees for a quarter mile or so, or live in a wooded area you can probably safely use the exposure B category retrofit information. However, If a 600 foot wide lake, large open field, or golf fairway starts within about 300 feet or less of the house, it would be prudent to use the exposure C category retrofit information.

The Basic Design Wind Speed reflects the long term likelihood that winds of that strength will hit the house. By studying the paths, sizes and intensities of hurricanes going back to 1850 engineers have determined the likelihood of hurricanes of various intensities occurring at any particular area of the hurricane prone coastline of the United States. The way the wind risk maps for hurricane prone areas have been prepared, there is roughly a 40 percent chance that a hurricane will impact the house with wind speeds equal to or greater than the basic design wind speed during a 50 year period. Because these maps can be hard to read and because the building department may have better defined the exact location of the lines of the map you will be best served by calling the local building department to learn the design wind speed for the area where the house is located. While you are doing that you could ask about the wind exposure. However, they may be reluctant to tell you the exposure category because they may think that an engineer should determine it.

4.0 Gathering information from the attic – Attic Inspection

As you might suspect you need to collect information from the attic about each of the two retrofit activities, namely strengthening and bracing each gable end wall and strengthening the wall-to-wall connections. With that collected information, you can decide on the methods to be used, make a plan, and develop a shopping list of materials.

To help prepare you to decide on the methods to be used, it is suggested that you read this section and Sections **5, 9, 10, 11, and 12** before collecting information. Section **9** gives detailed instructions on basic elements and steps used to strengthen and brace the gable end wall. Sections **11** and **12** suggest ways for dealing with usual cases or things that may be in the way. Section **10** gives detailed instructions for strengthening the wall-to-wall connections. The reason for reading these other sections is that at almost every gable end, there will be at least a little something that requires adapting or altering the straight forward procedure outlined in Section **9**. This guide has anticipated many of these situations and provides work arounds for them. These 'little somethings' can be obstructions or impediments that prevent following Section **9** procedures for installing Horizontal Braces on the floor of the attic or installation of Retrofit Studs at the gable end. The reason for reading these sections before going into the attic is so you will have some ideas ahead of time of possible work arounds.

To make collecting information easy several documents have been prepared to try to minimize the number of trips that have to be made into the attic. They are an **Attic Inspection Checklist**, a **Sample Sketch Page**, and a blank **Sketch Page**. A helpful document for collecting information about wall-to-wall connections is the **Wall-to-Wall Connection Details**. Click on these items to view them and then print them. Notice that at the top of the **Attic Inspection Checklist** there is a list of things to take into the attic. Be advised that there is so much to observe that good notes will reduce the number of trips that you have to make into the attic.

General description of what you will do in the attic: The numbers in brackets such as **(101)** refer to lines on the **Attic Inspection Checklist**. You should print out one copy of the **attic inspection checklist** and enough copies of the **sketch page** to have one for each gable end that you plan to retrofit. The following paragraphs walk you through the **attic inspection checklist** as well as providing step by step instructions for completing the **sketch pages**.

First Step - Making and Recording General Observations: **(101)** Determine whether the roof structure uses trusses or rafters, a description is on the **attic inspection checklist**. Then, using a clean **sketch page**, modify it if needed to show the outline of the gable end wall. It may be a simple triangle (in which case you don't need to do anything to the starting outline shown) or it

may have one or two ends cut off. Dimensions are not necessary for this. The slope shown on the Sketch Page is not important and so does not need to be adjusted.

Next, determine if the gable end wall is made of a truss or is conventionally framed. That is easy to determine. Trusses are manufactured units that generally are of triangular shape and use metal plates, not nails, of varying sizes to hold their parts together. The plates can range in size from 1" by 2" to larger than 10" by 12". In contrast a conventionally framed gable end wall probably looks like an ordinary wood frame wall that happens to have a triangular shape. Older homes may have trusses made by carpenters that have plywood gussets that join framing members together or that may be bolted together. **(102)** The important issue really is not so much whether the gable end is a truss or is conventionally framed, but instead whether the studs are flat against the wall or perpendicular to the wall. The studs that are part of factory made trusses have their flat faces (3-1/2") against the gable end whereas the studs of conventionally framed walls have their 1-1/2" edge against the wall. **(103)** If you find trusses, you need to note whether there are diagonal members in the gable end truss or whether there are just vertical studs with their faces flat to the wall. **(104)** Check the number that corresponds to the spacing of the gable end studs. Common spacings are 16", 24", 32", and 48". The most common is 24". Measure from similar points on the studs. **(105)** Make a note if there two sets of studs, some that are part of the truss and others that have been added. If there are added ones it is because carpenters added them so that nails on the siding on the gable end wall aligned with the nails on the wall below. This is a relatively common issue.

Second Step – Sketch in the General Information: **(201)** Add vertical lines for each of the gable end wall studs that appear to be longer than 3-feet. Measure lengths of these studs and enter the general information on the **sketch page** for the gable end being evaluated. Sketch all the studs 3' and longer by drawing a simple vertical line as suggested on **Sample Sketch Page**. Their locations need not be precise. **(202)** Show the length of each of those 3' and longer studs. The length is determined by measuring from the top of the ceiling framing member (top of ceiling joists or top of the bottom cord of the truss) to the bottom of the roof framing member (bottom of the rafter or bottom of the top cord of the truss). Measure along the longer side of each wall stud. The length is not particularly important at this point in time other than to help make sure that you get enough lumber to complete the job. The 3" accounts for the thickness of horizontal braces that will be added. You will better appreciate the significance of the 3" as you read further in this guide. **(203)** If you do see diagonal members, called webs, sketch their approximate locations using dashed lines. Their precise locations are not needed. Hopefully, the **Sample Sketch Page** will help give you an idea about what you need to draw and note on the sketch page. **(204) Optional:** Indicate the roof slope if you choose to figure it out. There is no compelling reason to know it.

Third Step - Detailed observations of existing studs: **(301)** Each existing stud of the gable end that is 3' or longer needs to be evaluated to be sure that on one side or the other of it a Retrofit Stud can be installed and installed effectively. Retrofit studs need not be installed on the same side of each existing stud. An obstruction that may be immediately apparent is that of webs of trusses. However, this is easily solved using a method described in Section 13. Other impediments to the installation of retrofit studs are objects such as pipes that preclude installing a retrofit stud. Usually there is an object on only one side, not both. So if there is an object on only one side you can simply note that with an 'X' on that side of the existing stud on the sketch and with an arrow on the other side of the existing stud. If there is the very unusual case of an object on both sides mark each side with an 'X'. **(302)** It is important to note whether an existing stud has been cut, that is that it is not full length. A retrofit stud cannot be installed effectively if the stud does not run the full length from floor framing member to ceiling framing member because the integrity of the existing stud was assumed in the engineering. An existing stud may have been cut so that a gable end vent could be installed. If a cut stud is found that fact should be noted on the sketch along with the reason it was cut, e.g. gable end vent. Note any such existing studs and indicate as a reminder the reason the stud was cut.

Fourth Step - Detailed observations for the feasibility of installing horizontal braces: **(401)** On the sketch at each existing stud to be retrofitted sketch in a diagonal line at the top and bottom of the stud to indicate a horizontal brace. **(402)** Evaluate each such existing stud to determine if a 6' long horizontal brace can actually be installed that will line up with both the existing stud and the location of the retrofit stud. If a brace can be installed then indicate it with a little check mark. This includes braces that may take some work to fish them under a wire or something, or running the brace a bit non perpendicular to the wall to skirt something like a recessed light. As a reminder you might add a little note to yourself indicating what the obstruction was. **(403)** If a 6' long brace cannot be installed, but a 4' one can, then indicate that on the sketch with a reminder about why. In addition you need to indicate the depth of the face of the existing floor and ceiling framing members. They may not be the same so look at each. **(404)** If a 4' horizontal brace cannot be installed, then add a note describing the obstacle. It could be something like an attic access or air conditioning equipment.

When you have gotten to this point, reviewing your observations may save you another trip into the attic. It is recommended that for each existing stud that is to be retrofitted you look carefully to determine that horizontal braces can be installed and that a retrofit stud can be installed. An effective way to do this is to simply start at one end of the attic, starting where the existing stud is 3' or longer, and ask yourself 1) can I install a Horizontal Brace on the attic floor in a straight forward manner, 2) can I install a Horizontal Brace on the bottom of the roof framing in a straight forward manner, and 3) can I install a Retrofit Stud in the usual manner. If the answer is yes to all three then that is great. That will be the usual case. However in practically every gable end there will be something or another that requires a little adapting. Making notes on the sketch

of installation issues will make planning easier and reduce the chance of forgetting details. You can see how that was done on the **sample sketch**.

Fifth Step – Collecting information for strengthening wall-to-wall connections: Observe the construction of the top of the lower wall and the bottom of the gable end wall. Start by trying to find the sketch in Figure 12 or 13 that most closely resemble what you observe in the attic. There are two fundamental types of lower walls, wood frame walls that might be 4” or 6” wide (Figure 12) and concrete block walls (Figure 13). Next narrow those drawings down by finding the one that also matches the upper wall. Circle that drawing. For the upper wall there are quite a few possibilities so look carefully when comparing the wall with the drawing. If you don’t find one that is a good match then circle a lower wall that matches and an upper wall that matches even if they are on different drawings. With this done you have done **(501)** and **(502)**. **(503)** Take pictures that show how the upper wall rests on top of the lower one and where and how they meet. **(504)** Observe and photograph any signs of connections between the gable end wall and the wall below. Make notes of what you observe. This will be used to help you decide whether you think you can implement one of the connection methods suggested later in this guide. What you will not be able to readily detect is whether straps were used to connect the lower and upper walls since they may be on the outside of the wall framing. In some rare instances, plywood may have been installed in such a way that it provides a connection between the upper and lower walls. If you find wall construction that match the sketches in Figures 12 or 13, it is a safe bet that you should plan on strengthening the connection between the lower and upper walls.

In other rare instances, at least for older homes, the wall studs may continue without a break from the floor below all the way up to the roof. This type of framing is known as balloon framing and is one of the best ways to make a very strong gable end wall. If you find balloon framing, what you see in the attic will not match any of the drawings in Figure 12 and you probably do not need to brace the gable end. The masonry alternative to balloon framing is to continue the masonry wall all the way up to the roof and to install reinforcing in the wall that extends throughout the height of the wall. Again, if you find this situation, it will not match any of the sketches in Figure 13 and you may not need to brace the gable end. Many older masonry walls did not have vertical reinforcing steel and they may not have sufficient strength to withstand the wind pressures developed at Design Wind Speed.

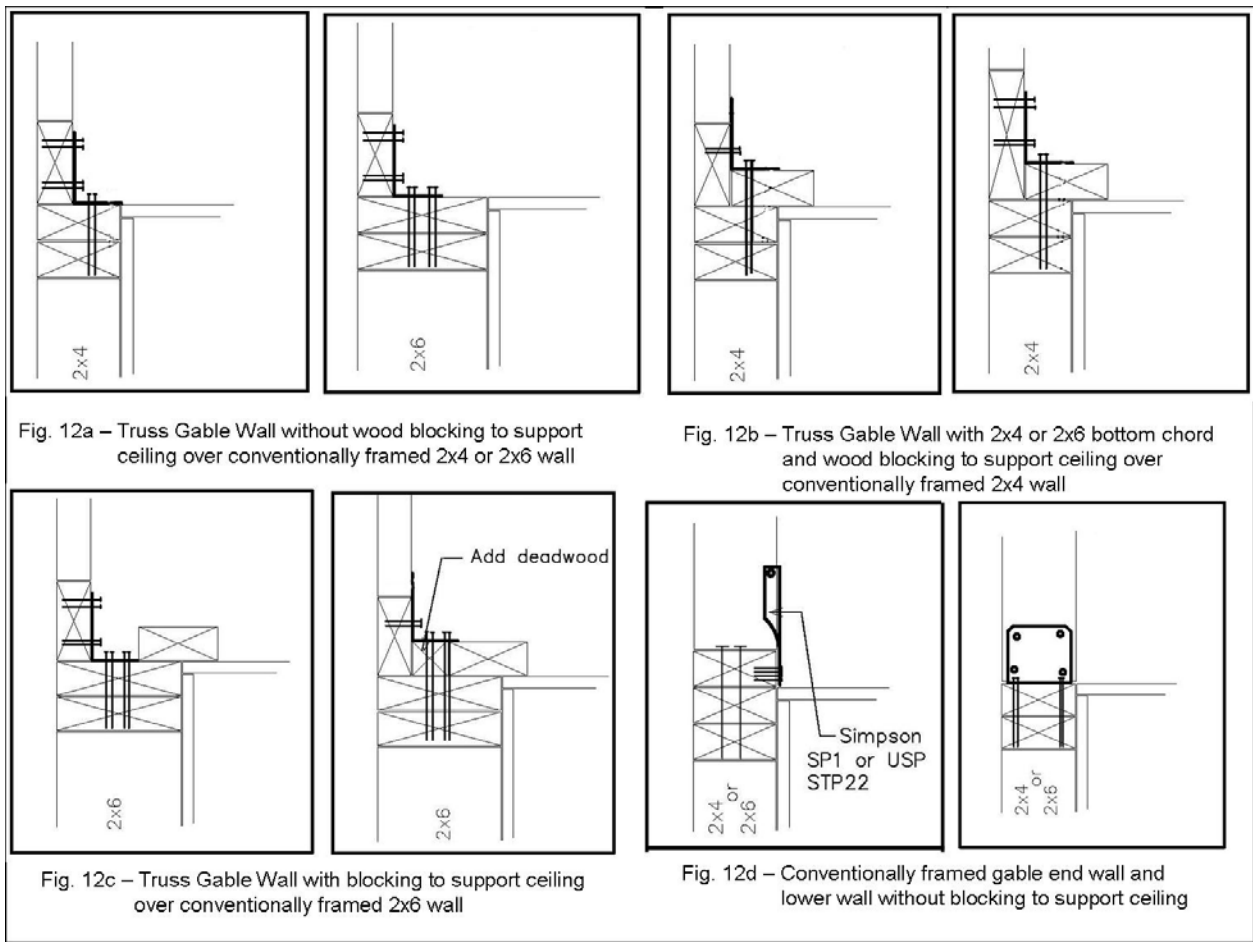


Figure 12. Gable end walls over conventionally framed wood walls.

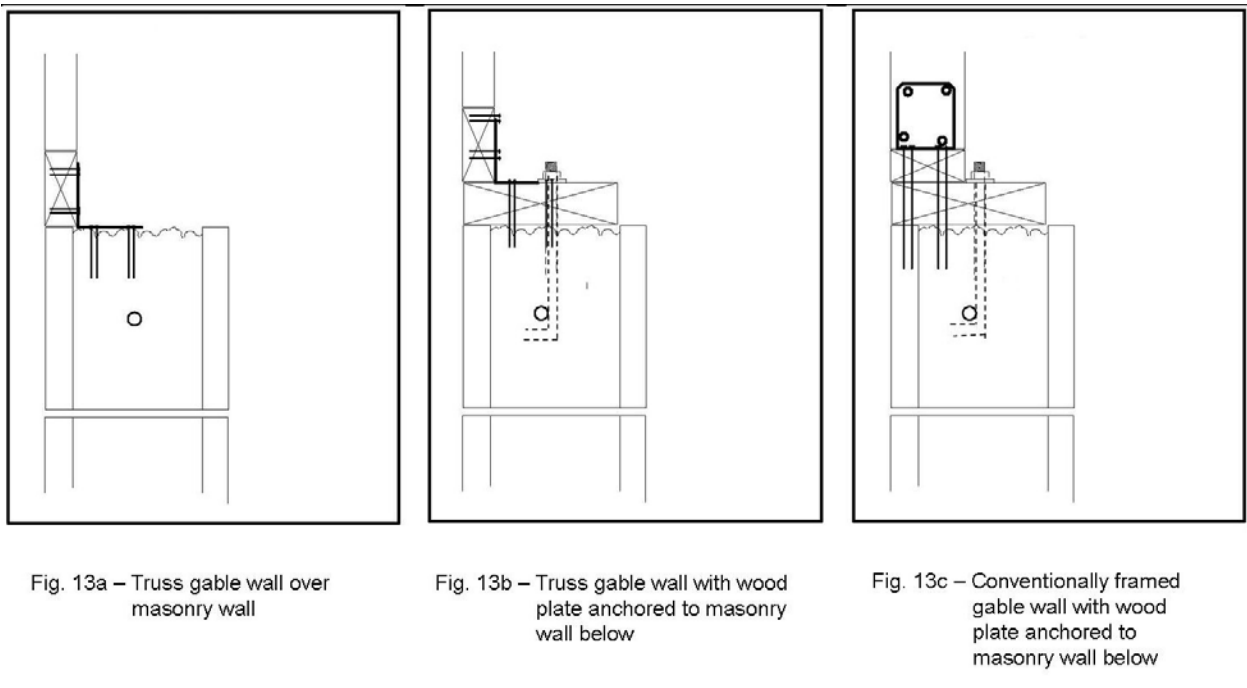


Figure 13. Gable end walls over masonry walls

Check Each Gable End: Each gable end should be inspected because each is apt to have some differences that will affect how you do things. In addition each stud location should be evaluated for the presence of obstructions. Good notes and lots of photos will reduce the likelihood of repeated trips.

If you have read Sections **6**, **10**, **11**, **12**, and **13**, printed the suggested pages, and gathered the tools you will need in the attic you are now ready to make a trip into the attic and collect the information on each gable end to be retrofitted.

5.0 Deciding on methods and making a Working Sketch

Planning for the two major gable end retrofitting tasks of making the gable end strong and that of connecting the walls together should be relatively easy now that you are armed with the information you collected from the attic. From the **Sketch Page** you completed in the attic, knowing the **Exposure Category** (see Section 3), knowing the **Basic Design Wind Speed** (see Section 3), and referring to **Tables 1 and 2** you can decide on the methods you will use and then add those details to the **Sketch Page** to make a **Working Sketch** that you use for making a shopping list of materials and for taking into the attic to guide you in executing the retrofits.

Gable ends should be constructed with plywood, boards or simulated boards made of hardboard, (sheathing) and covered with vinyl, aluminum, or stucco or a combination of sheet material. However, in some cases the sheathing material will be just foam or felt paper covered by aluminum or vinyl siding. If there is no structural sheathing or if the plywood has deteriorated because of water or termites, it should be replaced to provide the structural strength needed. See Section 14 for a more detailed discussion of gable end siding.

Table1

GABLE END RETROFIT ELEMENT SIZING AND FASTENING

Exposure Category	Maximum 3-Sec Gust Basic Wind Speed	Maximum Height of Gable End Stud ^{b.}			
C	110	8'-0"	11'-3"	14'-9"	16'-0"
C	120	7'-6"	10'-6"	13'-6"	16'-0"
C	130	7'-0"	10'-0"	12'-3"	16'-0"
C	150	6'-6"	8'-9"	11'-0"	16'-0"
B	110	8'-0"	12'-3"	16'-0"	N/A ^{c.}
B	130	8'-0"	11'-3"	14'-9"	16'-0"
B	140	7'-6"	10'-6"	13'-6"	16'-0"
B	150	7'-0"	10'-0"	12'-3"	16'-0"
		Method #1	Method #2	Method #3	Method #4
		See figures A - 2 and A - 7	See figures A - 3 and A - 8	See figures A - 4 and A - 9	See figures A - 5 and A - 10
Step	Retrofit Elements				
1	Minimum size of Horizontal Brace	2x4	2x4	2x4	2 each 2x4
2	Minimum number of 3" long fasteners to connect Horizontal Brace to existing stud	3	3	3	3
3	Retrofit Stud to Minimum	2x4	2x6	2x8	2 each 2x8
4	Flat Strap Length Minimum length	21"	30"	38"	2 straps 30"
5	Minimum number of 1 1/4" long fasteners to connect Flat Strap to Retrofit Stud	6	9	12	8 on each strap
6	Maximum on center spacing of 3" long fasteners to connect Retrofit Stud to Existing Stud	6"	6"	6"	6"
7	Minimum number of 1 1/4" long fasteners to connect Strap to Retrofit Stud	6	9	12	8 on each strap
8	Compression Block Minimum length	11 1/4"	13 3/4"	16 1/4"	17 1/2"
9	Minimum number of 3" long fasteners to connect Compression Block to Horizontal Brace	6	8	10	12

a. Interpolation between given wind speeds not permitted.

b. Existing gable end studs less than or equal to 3'-0" in height shall not require retrofitting.

c. N/A = Not Applicable. Exceeds 16'-0" maximum height.

Fasteners shall be #8 screws or 10d nails

Table 2

Spacing of Brackets Connecting Gable End Wall to wall Below

Exposure Category	Wind Speed, mph	Maximum Spacing of Right Angle Gusset Brackets
	Maximum 3-Sec. Gust	
C	110	38-inches
C	120	32-inches
C	130	28-inches
C	140	24-inches
C	150	20-inches
B	110	48-inches
B	120	40-inches
B	130	36-inches
B	140	30-inches
B	150	26-inches

Making a Working Sketch: First, you might want to redraw each **Sketch Page** you made in the attic to make it more legible. To the redrawn Attic Sketch you will add installation details to make them similar to the **Sample Working Sketch**. This will result in sketches that you can use in the attic to guide you in the retrofit details. Each sketch will contain all the information you need to retrofit a gable end wall. If you have easy access to a copy machine or scanner you might want to make copies of the redrawn attic sketches before you add retrofitting details to make them into **Working Sketches**. When adding details to the Sketch Page to make your Working Sketch it would be best to not use a pen whose ink runs when it gets wet as you will probably get sweaty in the attic. If you prefer working with such a pen that is fine, you can just use a copy machine to make a copy to work with in the attic.

From Table 1 you can get material sizes and numbers of materials and fasteners to add to your **Working Sketch**. You use the table by selecting the Exposure Category and Wind Speed for the location of the house as was described in Section 4. Read across the top of the table for the exposure category and the wind speed to find the retrofit stud length that corresponds to the stud to be used. Then read down the table to the numbered rows 1 through 9 to find the material sizes, numbers of materials and fasteners. Before you enter the information onto your **Working Sketch** you need to refer to your sketch to see if the usual methods outlined in the table can be used for a particular stud location or if another method will be used. The other methods for horizontal braces can be found in section 11 and in section 12 for retrofit studs. The **Sample Working Sketch** gives you a suggestion of how you might add information from rows 1 to 9 specifically Horizontal Brace size and number (one 2x4 or two 2x4s), Retrofit Stud size (2x4, 2x6, or 2x8, or two 2x8s), Strap length, number of fasteners at each end of straps, minimum Compression Block length, and number of fasteners in Compression Blocks.

This essential information will set you on the way for a good and effective strengthening of the gable end. Section 9 gives you step-by-step retrofit implementation details.

6.0 Selection of Materials and Tools

Material takeoff: The **working sketches** you developed in the previous section will give you a good base for determining what materials will be needed. You may want to purchase just the materials you will need for a single gable end because as you work you may find you will make some changes that might affect the lengths of lumber. To help you make up a shopping list, we have prepared a **Table 3** which provides a takeoff list.

Purchasing materials: Most everything needed is available at most home improvement supply stores and suppliers of lumber and other construction materials. Some materials like the HGA and HGAM connectors may have to be special ordered.

Selection of methods and materials: You have a number of choices of materials. For example, you can choose the kinds of lumber, types of straps, and types of fasteners. These choices are discussed in the rest of this section. **Table 4** below is intended to help you determine if you want to use nails or screws as the fasteners and then determine which method of installation you want to use. The bottom line is that most people will find using screws has the most advantages especially if they already have a good cordless (battery) driver/drill or have been looking for an excuse to buy one. Experienced carpenters who have pneumatic nailers made for use with straps may well prefer to use nailers. Last on the list of preference is the use of a hammer. A cord operated drill screw driver is a perfectly good choice. More discussion follows the table.

Table 3

Material takeoff List

Item	Method #1			Method #2			Method #3			Method #4			Total
	Number	Quan.	Total	Number	Quan.	Total	Number	Quan.	Total	Number	Quan.	Total	number
	of #1	Each	number	of #1	Each	number	of #1	Each	number	of #1	Each	number	to buy
2x4x8'													
2x6x12'													
2x8x16'													
Flat strap, 12"													
Flat strap, 24"													
Flat strap, 36"													
Coil Strap													
1 1/4" fasteners													
3" fasteners													

TABLE 4

COMPARISON OF FASTENERS AND TOOLS

	Precision of fastener placement	Ease of use	Ease over-head	Other ease of use issues	Number of hands	Speed	Cost	Risk of damaging ceiling or wall finish
Screws with cordless	Very good	Best	Best	Battery charging	1 maybe 2	Slowest	High	Low
Screws with chorded	Very good	Good	Very good	Power chord	1 maybe 2	Slowest	High	Low
Nails with pneumatic nailer	Very good to worst	Good	Good, but heavy	Hose and compressor	1	Fastest	Low	Middle
Nails with hammer	Very good	Worst	Worst	Can be tiring	2	Slow	Low	High

Selecting fasteners: **Table 3** above tells you of the advantages and disadvantages of both screws and nails. You can mix and match between screws and nails. Most people will be better off using screws. Experienced carpenters may prefer nails for some applications. Care should be taken when using nails on lumber that has brittle or fragile finishes applied to it. Such finishes include drywall, plaster, and stucco. Being able to accurately position fasteners is important for the fasteners to be effective and reduce the chance of splitting wood. Screws and hand driven nails provide the best precision.

The cost difference between nails and screws is about \$25 for a big gable end. The extra time and cost of screws may well be worth the reduced risk of damaging ceiling finishes.

Selecting the type of screw head: Most people that use square head drive or Phillips-square head screws are convinced that they are much easier to install than screws with just Phillips heads; because, they don't fall out of driver tips as easily as screws with only Phillips heads. Don't get confused by the term above of 'Phillips square head'. It means that either kind of driver bit can be used. Experience with some brands of screws with Phillips-square heads has shown them to be just as good as square head screws. A significant advantage to screws and especially square head ones is that they can be placed on the tip of the driver/drill and stay there while starting a screw into wood. For shorter screws this makes installation really easy by freeing up a hand. Driving three inch screws may well require two hands, one for the driver/drill and another to keep the screw from wobbling until it gets started into wood. It is still easier than a hammer and nail.

Selecting Nails: There are nails for hammer driving made specifically for use with straps or connectors that require nails to be 10d in diameter (0.148") but only need to be 1-1/4" long. Nails designed specifically for use with straps are readily available at home supply stores. They are 1-1/2" long instead of the minimum of 1-1/4" that is necessary. Longer does not hurt anything. It is essential that the diameter be that of a 10d nail. Smaller diameter will not meet the engineering requirements and larger will not fit into the punched holes of connectors. Usually the model number indicates the diameter, e.g. N10HDG and NA9D or N10GC. The shorter length of these nails will save a lot of effort and time compared to driving a full length 3" 10d nail. 10d nails that are specified to be 3" long need to be that long and need to have a minimum diameter of 0.148". Larger diameter fasteners should not be used because the edge and end-to-end spacing of the fasteners were specifically designed for 10d nails or #8 screws.

Selecting Straps: Factory made flat straps are available at most home supply stores in all the sizes needed except for the 38" length required for Method #3 where coil strap will have to be used which may or may not be available at home supply stores. Flat straps are the easiest to use. The problem with coil strap is the cost of having to buy a whole roll and that it requires that each strap of the heavy gauge be cut to length. The gauges of coil strap available at home supply

stores are 16 gauge which makes the coil so heavy that you won't want to lug it through the attic. Instead cut the straps to length out of the attic where it will be easier to use a hacksaw or heavy duty snips.

Flat straps: The specifications for straps are that they be the sort manufactured for making structural connections for the construction industry. They are available at most home supply stores. Straps less than 30" long need to have a thickness of at least 20 gauge metal sheeting. Lower gauge means greater thickness. Heavier, that is lower gauge, straps are perfectly ok to use. You may find that some stores do not stock 20 gauge straps, but only the heavier and stronger 18 gauge ones. That is fine. They don't cost much more. Common model numbers for flat straps used by several manufacturers are LSTAx or MSTAx where xx is a number that indicates the length. Some manufacturers of connectors and straps add 'Z' to the end of the model number to indicate that the connector is more rust resistant. This is probably of no meaningful benefit for straps in attics, but of course it does no harm. The width of these straps is 1-1/4". They have properly spaced punched holes for fasteners.

Coil straps: Straps 30" and longer must be 18 gauge or heavier. Flat straps are readily available for the 30" length, but not for longer than 36". 38" is needed for Method #3 as can be seen on row 4 of **Table 1**. For that one must resort to coil strapping. Again, it must be 18 gauge or heavier. Straps used for hanging plumbing pipes are absolutely not acceptable. The problem with coil strap is that one has to purchase at least a 25' roll and maybe 100 or 200' roll at a time depending on what is available. That makes it costly. At least one connector manufacturer does make a 1-1/4" wide by 48" long strap that likely would need to be special ordered. It has the advantage of being made of 16 gauge metal which is even heavier than 18 gauge, but it has the disadvantage of being difficult to bend because of its thickness. A vise would almost be a necessity for making sharp (not rounded) bends. Common model numbers for coil straps are CS16, CS14, etc. Where the number indicates the gauge of the strap. They are available from some sources in roll lengths of 25', 100', 150', or 200'. Twenty five foot rolls are long enough for many gable ends. Given a choice select the minimum thickness strap to make bending easier. The strength of thicker straps simply is not needed.

Selecting lumber: The lumber that was specified by the engineer for these retrofits was assumed to be at least as strong as the species of wood that is called SPF (Spruce Pine Fir) and that its quality level or grade was No. 2 or better. SYP (Southern Yellow Pine) or SP (Southern Pine) is stronger than SPF and so is just fine to use except that it is heavier than SPF and so it will be harder to carry into an attic and it will be harder to start fasteners into this harder wood. No. 2 is better than No. 3 and stud grade. No. 1 and Select grades are stronger and so better. The grade and wood species are stamped on each piece of lumber. Because some lumber comes from other countries the SPF designation for the species of the wood may not be used. Instead the label may be on the price label where the lumber is displayed. You may have to look around to find a

stamp that is legibly printed. When you are picking through lumber to purchase, select lumber that is not excessively twisted, cupped, or crowned. The easiest way to judge this is to look down the length of each piece of lumber because that tends to reveal all the flaws. Because wood is a product of nature one cannot expect perfection. In conclusion it is important when buying lumber that you make sure it is at least as good as SPF and has a grade of No. 2 bearing in mind that 2 is better than 3.

Tools: The following is a list of the tools that can be used. Don't worry you don't need them all because the list includes some alternatives that will be discussed next.

- Cell phone or wireless extension phone (Safety precaution)
- Driver bits
- Driver/drill, or impact driver drill, battery powered or cord operated
- Extension cords w/ 3way
- Fan. (Depends on the time of year and time of day.)
- Hammer
- Heavy duty snips or hacksaw
- Knee board, custom made
- Lights. Two are recommended.
- Nippers or wire cutters
- Pneumatic nailer(s) or airless nailers
- Screw driver, flat drive, medium size
- Skill saw, battery or cord operated
- Tape measure
- Tool and parts carriers.
- Tool belt or parts pouch.
- Tools for wall-to-wall connections: optional hammer drill, nut/socket wrench,*

Cost of fastening tool: A hammer is the cheapest if for no other reason than you probably already have one. A line powered drill/screw driver is another tool that almost every one owns. A battery (cordless) drill/screw driver is also a tool many people have. The issue with a cordless drill is the capacity of its batteries. Most homeowner cordless drills do not have batteries with enough staying power to allow continuous work in attics. A pneumatic nailer is a tool that few people have and it requires dealing with dragging a trailing hose behind you and having a compressor. Some nailers made especially to drive 1-1/4" long nails into straps do not have the ability to drive the 3" long nails required for fastening Horizontal Braces, Retrofit Studs, and Compression Blocks. That could mean having two nailers, one for 1-1/4" fasteners to be driven into straps and another for driving 3" nails. Few people will have other uses for nailers whereas many people will appreciate having a good battery driver/drill.

Drill/screw driver, battery or cord operated: Table 4 and the discussion below it may have helped you decide whether you want to use nails or screws. The discussion immediately below further describes the issues involved.

Battery (cordless) driver/drill or impact driver: If you choose to use a cordless driver/drill, choose one with two good batteries with some power behind them and staying power to drive screws for several hours of work. This is what is necessary to make a battery drill/driver a completely effective tool. Such a driver/drill driver can be costly, well over \$100.

Corded electric drill: Practically any cord operated electric drill can serve the purpose quite well. However, having a cord means you have to route extension cords to where you will be working, keep them untangled from things in the attic, keep them untangled from your body especially your feet, and having to be sure you don't trip on them. A disadvantage of most corded drills is the lack of the nice feature of a clutch.

Tips for screw driver: Even magnetic removable tips for screw drivers have a tendency to fall out so you are very apt to lose them in the attic especially when they fall into insulation. Screw driver tips tend to chip or dull, especially Phillips ones. And tips tend to develop rounded edges especially Phillips ones making them ineffective at driving. For these reasons having a half a dozen spares in the attic with you is a good idea. They cost less than \$1.50 apiece so keep them on hand. Again, square head screws tend to cause fewer problems.

Pneumatic nailers: Pneumatic nailers are unquestionably fast tools. Their disadvantages are the cost of the nailers, hoses, and compressor and having to deal with a compressor hose in an attic and having to route them and keep them untangled. Two lengths of fasteners are used in this retrofit work. 1-1/4" long ones used to secure straps and 3" long ones to secure lumber to lumber (Horizontal Braces to framing members, Retrofit Studs to Existing Studs, and Compression Blocks to Horizontal Braces). Pneumatic nailers are great tools for both lengths. For the 1-1/4" nails used in straps it would be best to have a nailer that is designed for use with metal connectors because they facilitate lining up nails with holes in connectors. Some of these nailers do not drive longer nails such as the 10d 3" long (0.148" diameter) ones needed.

Hammer: A hammer causes a lot of shock to framing members which can cause brittle or fragile wall or ceiling finishes to be cosmetically damaged by cracking or falling off. Pneumatic nailers impose less impact. Screw drivers impose practically no impact. Hammer driven nails installed to the bottom of an overhead Horizontal Brace is not easy especially when you are doing it over your head in an attic. Starting a couple nails before lifting a Horizontal Brace overhead does make the task easier.

Other Tools:

Skill saw: A power saw either line powered or battery operated is a necessity. A battery one is handier because you won't have to fight extension chords, but a line powered one will cut faster. The cost of a battery saw is probably not justified because of its consumption of a battery charge.

Tape measure: A tape measure with tape that is less than 3/4" wide tends to be so flimsy that it is not handy to use. You don't need a long tape measure. A 12 or 16' one is long enough.

Nippers or wire cutters: When pushing a retrofit stud against gable siding, nippers or wire cutters capable of cutting nails may be handy to use to cut off nails that may have missed hitting the existing studs.

Screw driver, flat: A medium sized screw driver for flat head screws is handy for prying up staples that hold wires.

Lights: Because you will be working against the gable end wall your body will tend to create shadows exactly over the area where you will be installing nails or screws. Light coming from a couple of sides really makes fighting shadows less of a problem. There are a number of different kinds of lights that can be used none of which have clear advantages over the others. Halogen lights with clamps provide very good lighting, but get very hot and are a potential fire hazard should they come into contact with combustibles. The risk is created by their clamps coming loose from their anchorage on framing. Because of the fire hazard it is recommended that halogen light fixtures always be turned off or disconnect when leaving the attic. This discussion is not to discourage you from using halogen fixtures, but instead to be careful. They do provide excellent lighting. Fluorescent power line operated or battery operated lights provide good general illumination if a bit on the dull side. Line powered ones tend to be fragile. 100 watt incandescent bulbs mounted in shrouds with clamps provide good illumination, but the bulbs are subject to burning out when bumped and the clamps tend to be not very secure. If you choose to use incandescent bulbs, then keep spares in the attic. Experience has shown that bulbs made for high shock use are simply bulbs designed to work at lower temperatures which is a disadvantage to you because they don't produce as much light.

Flashlights of the ordinary kind are not too helpful for working. Most require a hand to keep them in position and most are too small to provide general illumination, and they have very limited battery life. This is not to say that a flashlight is not a handy light to have in an attic especially when attempting to view one's immediate work area. Halogen or high intensity flashlights as they are sometimes called are excellent for investigating things in an attic like roof leaks. They are heavy, bulky, and don't hold a charge long.

Some people really like to use LED lights that come on a head band. They provide direct light focused on where one is working, do not require a hand, batteries last long enough to work, they are light weight, relatively inexpensive (\$10 to \$20 range), and are available at places discount stores. An advantage of such a light is that even though you may have flood lights of some sort broadcasting light from a couple of directions you can still be working in a shadow that your body creates. They are not good for providing lighting in other than in immediate work areas so general illumination is still necessary.

Fan: Working in hot attics can be made more comfortable if a fan only does little more than just create a little moving air around you. It does not need to be powerful enough to clear the attic of hot air. A box fan has the advantage of being able to span framing members thus making its positioning easy beside they have the advantage of moving air over a large area.

Knee board: When it comes to making the wall-to-wall connection, a knee board will be appreciated because it spares some stress on your knees and makes working easier by providing a place to rest tools and parts. A knee board can be as simple as a piece of 1/2" or 5/8" plywood (3/4" plywood tends to be too heavy to move around easily) about 12" or wider. It should be long enough to span usual framing member spacing of 24", but not so long as to be cumbersome to position. 30" is a good length. Adding a 1x2 cleat across the short face of the bottom near each end will minimize the chances that the board will slipping off framing members. A Cadillac version would have some padding on the top surface. A hole for gripping it would be handy.

Cell phone or cordless phone: A cell phone or cordless phone is a safety device so that you can seek help without leaving the attic.

Tool and parts carrier: A plastic parts tray with sections for holding various small parts can be a great help. See the discussion near the end of next section for more about adapting carriers to make them easier to use.

Tool/parts belt or pouch: Some people will find a tool belt annoying to use in the attic because it will catch on truss members and its contents of screws or nails may dump out as a result of some of the positions you may find yourself in. If the attic is conventionally framed with rafters and ceiling joists then a tool belt may be handy and not present problems. Because not many different kinds of tools are necessary a tool belt will likely be used primarily to hold fasteners.

Heavy duty snips or hacksaw: If you use coil strap it will likely be of a heavy gauge that is not easy to cut. A hacksaw to start a cut by making a score across the face of the strap will make it easy to bend the strap back and forth at the score to snap it off.

7.0 Working in attics

The two most important issues in working in attics are travel and safety. Travel is discussed in this section and safety in the next.

Getting materials into attics: Three ways to get boards and lumber into an attic are directly through an attic access, through a gable end vent, through a temporary hole you make in the gable end and then patch, or through a gable end whose siding you have decided to replace with new stronger siding. Even if there is not much headroom because the access is near eaves and even if an attic access is a small one, you can usually still feed at least 8' long lumber through the opening. You might be surprised to find that you can feed 14' long lumber into just a little more forgiving access. It may take some weaving, but it may well be possible. The advantage of being able to feed long boards or lumber in is that it is long ones that are ideal for making walking paths should you decide to make them. For gable ends that require long retrofit studs it will save a lot of effort if full length retrofit studs can be used because that will spare one from having to make splices. Splices are easy to execute, but they do take time and additional materials.

Another option for getting boards and lumber into the attic is through a gable end vent that has been removed. This requires an investment in time to remove and then replace the gable end vent. However, it may be worth doing when the option is traversing an attic with materials in hand. It may be especially worth while if the gable end vent is to be blocked as described in Section 13. Making a temporary hole to feed boards and lumber into an attic likewise requires an investment in time and requires patching afterwards.

Travel in Attics, a Walking Path: Air conditioning or heating duct work, air conditioning equipment, possessions, collar ties, webs of trusses, and diagonal braces can all compound the problem of traversing an attic to get access to a gable end. You may well find 1x4 boards or pieces of plywood in an attic that carpenters and others used during the construction of the house. And you will find that these boards do make it easier and less risky to walk. You will especially appreciate them when you are carry tools or materials. If the boards are not loose you will find them even easier and safer to walk on. They are a lot easier to walk on than the 1-1/2' edge of attic floor framing members and they reduce the chance of your foot slipping off. A common term used for 1x4 or 2x4 walkways in attics is "rat runs" for reasons you can imagine. If you are going to have to make a lot of trips in an attic, that is not easy to walk in, you should consider making it easier by adding walk boards. Furthermore, if you expect to have to walk back and forth a number of times, you might want to consider having the path two boards wide instead of single width staggered boards

Making a walking path: A path made of 1x4 boards is strong enough and wide enough for most people in most situations. If a path is to be used a lot then having it two boards wide might be useful. Select boards for your path that do not have knots larger than about $\frac{1}{4}$ of the width of the board. Large knots can weaken boards to the point that walking on them will cause the boards to break. Pine is usually a good wood to choose because it is strong. Spruce can be problematic depending on the grade, i.e. knots.

Each end of a walk board should rest solidly on a framing member so that it will not slip off and become a spring (diving) board. When adding walk boards one end of them will likely have to be trimmed so that it doesn't extend past the last framing member. Ideally, but not essentially, lay the 1x4's along a path in line with each other. If you do this, we recommend that you add (scab on) a 2x4 member to the side of the roof framing member where the two pieces meet so that each end of the 1x4's are well supported by a 1-1/2" wide support. Aligning the boards will minimize your making a misstep and putting your foot or worse through the ceiling when you thought the next step was going to be a continuation of the boards you were walking on.

1x4 boards may not seem very thick, but they only have to bridge about 2' so if they only have smallish knots they will be perfectly strong unless one jumps on them or one is particularly big. You can use 2x4s, but they cost more, are heavier to transport, and usually their additional strength simply is not required. 2x4s could conceivably be worthwhile if the floor is particularly bouncy or you are big. When you have finished retrofitting a gable end for which you installed a path you can leave them in place for future use, salvage them for use on another path, or salvage them for other purposes not related to gable end retrofitting. Be sure to secure any existing loose walk boards and plywood to minimize the chance of their slipping under foot. When carrying things it is fairly easy to slip off. The likelihood of causing damage to ceilings below will be reduced if screws, not hammer driven nails, are used to secure the boards. Just a few fasteners are sufficient to secure the boards and using just a few makes it faster to salvage the boards for another use. A disadvantage of using 1x4 walk boards is that they will not distribute one's body weight over as many ceiling members as 2x4 would. However, unless one walks with a heavy foot this probably would not be an issue.

Carrying materials in the attic: You will find a plastic carrying tray is handy to have because it will make carrying tools and fasteners and even straps easier. Having such a container right where you are working will give you a handy place to store tools while you are working without having to put them on the floor where they can get lost in insulation. To keep from having to balance the container on a framing member or placing it on the ceiling, think about securing a piece of plywood (long enough to span framing members, say 28") to the bottom of the container. You may also want to add cleats to the end of the piece of plywood, similar to those suggested for the knee board, to keep the container from sliding off the framing.

When carrying boards or lumber through an attic with obstructions that force you to clamber over things, it might be helpful to have a place to set the lumber down. If there are truss webs nearby you might be able to make a resting place by adding screws that would serve as stops to restrain boards and lumber so you have two hands free to clamber over obstructions.

Be respectful of AC ducts that you may have to clamber over or under. They and their joints can be fragile.

8.0 Safety

Attics can be dangerous places in which to work because of heat, falling and tripping hazards, protruding nails, and electrical shock hazards. A little caution will go a long ways to minimize these hazards. Bear in mind that if you get into trouble in an attic it may be very difficult for people in the remainder of the house or even in another part of the attic to hear your pleas for help. A cell phone or cordless phone is a valuable safety device should you need help. Other hazards include head bumps, head scratches from nails from roof decking, fatigue and wear and tear of knees.

Heat Hazard: Heat can be a real danger and a serious health issue that you can't safely ignore on warm sunny days. When working in an attic especially when starting in the morning when it is cool one may not fully appreciate the cumulative affect of heat and dehydration. It is not unusual to try an not loose time when the attic is cooler and consequently one pushes on to get just a little more work done, to not take breaks to cool off, and to not hydrate adequately. These can be dangerous tendencies that you should be on guard against.

Heat stroke: Heat stroke can make you very sick and can affect your balance and ability to think clearly. Drinking water does not replace the electrolytes you loose when you perspire and missing electrolytes are a key issue in heat stroke. You should go up hydrated and stay hydrated by drinking sports drinks with electrolytes. You should take breaks out of the attic and time the retrofits so that you do them in a cooler season. If you are working in the summer, stop working by 10 to 11 am, at the latest.

Ventilation: Ventilation can do a lot to make it more comfortable to work. However, ventilation will not solve the hydration issue.

Fall Hazard: The likelihood of falling can be reduced by being careful, having good walk paths and having good lighting.

Electric Shock Hazard: Shock hazards can come about because of frayed wires, wires damaged by vermin, nicked or frayed extension cords, open electrical boxes, existing staples and nails that have penetrated wiring, and your moving wires. Caution and prudence are the keywords.

9.0 Strengthening and Bracing Gable End Walls

Bear in mind that you may want to make the wall-to-wall connections before strengthening and bracing the gable end. This will depend on how you will be making wall-to-wall connections. See Section 10 to help you decide which to do first.

There are two types of obstructions that have been anticipated in preparing this retrofit guide. Specific guidance is provided for ways to work around these obstructions without reducing the effectiveness of the retrofits. One type is where there are obstructions that prevent the effective installation of a retrofit stud. These include gable end vents where the existing framing (existing studs have been cut so that a gable end vent could be installed) or where pipes or other objects are in the way. The alternative measure for this is discussed in Section 11. The other type of obstruction is where there are obstructions on the floor or ceiling of the attic that prevent the installation of horizontal braces that extend the minimum of 6' into the attic. Alternative measures for this are discussed in Section 12.

Horizontal braces attached to the tops of ceiling joists or the bottom chord of trusses: **Walk carefully.** If the ceiling framing members are bouncy you need to walk as gently as possible to avoid flexing them so much that cracks develop in drywall ceilings (especially at tape joints), cause drywall texture to fall off, or crack plaster. Most ceiling finishes are brittle and fragile. The advantage of installing bottom braces first is that they will help distribute your weight over several ceiling members (a large area) thus reducing the likelihood of causing too much deflection on a single member. This will reduce the chance of causing cosmetic damage to ceilings. Still, one should tread softly. If any boards or plywood is already in place, then be sure it is secured so it does not slide from under foot or flip up because you walked on an unsupported end.

Installing the bottom horizontal braces will give you a better walking and working surface than just the 1-1/2" edge of ceiling framing and makes doing the rest of the work easier. Next install all the upper Horizontal Braces. Having the lower and upper braces in place will allow you to make more accurate measurements of the lengths of the required retrofit studs. Figure 14 shows the positioning of top and bottom horizontal braces.

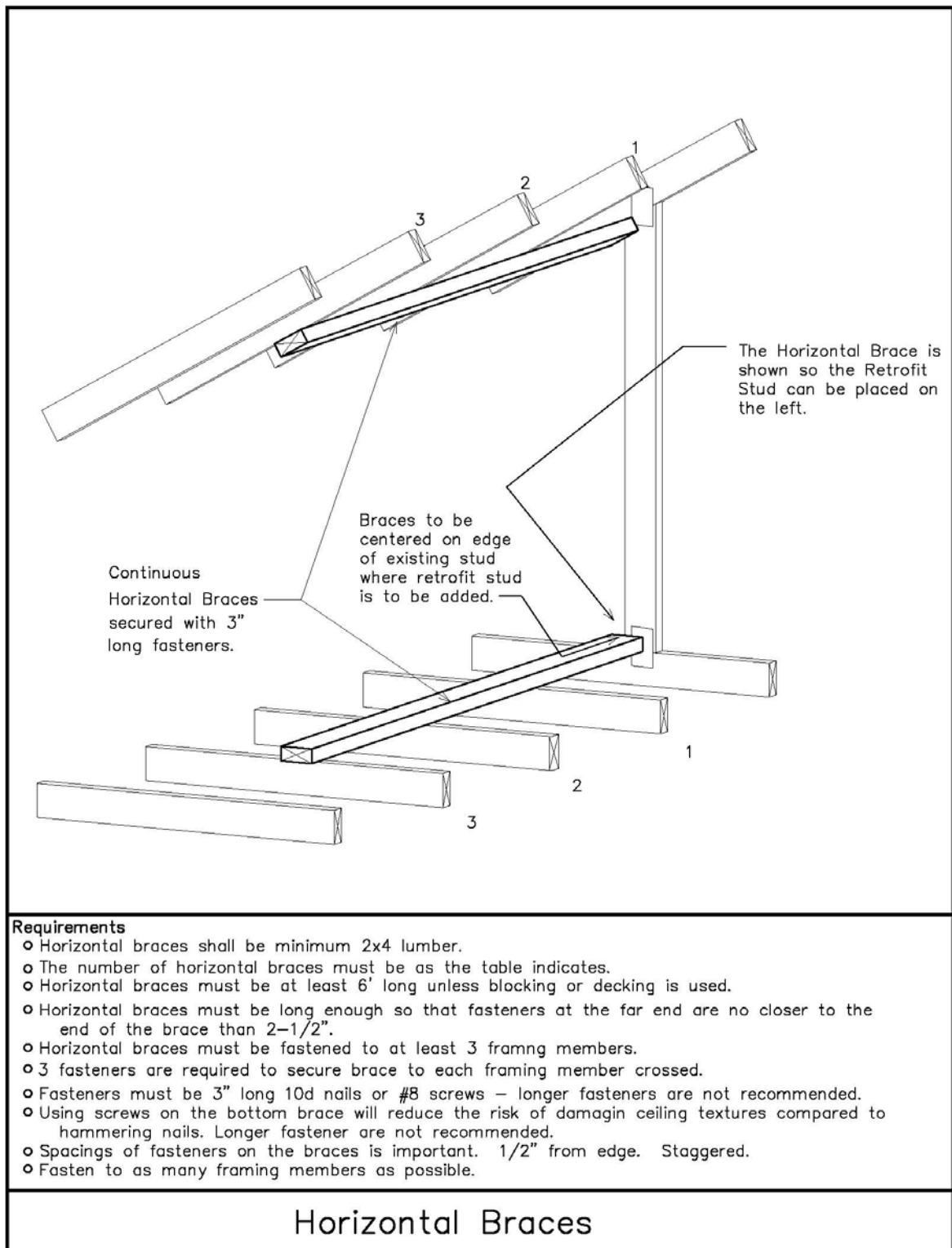


Figure 14. Sketch showing location of top and bottom horizontal braces

Where to install the horizontal braces: You have some flexibility in placing horizontal braces. Horizontal braces can be installed on either side of existing studs as long as that is where a retrofit stud can be installed. Horizontal braces can be run at an angle to avoid obstacles. They can be fished under some obstacles. If need be, they can even be shortened 2' if blocking is added and can be shortened even more if a plywood deck is installed that spans the area blocked by the obstacle. They do need to be secured to each framing member over which they cross, unless the member is near the wall and its only function is to be deadwood to support ceiling drywall. Reevaluate which side of an existing stud is the best place to install a retrofit stud. It is ok to switch sides back and forth depending on what works best, i.e. the retrofit studs don't have to be consistently on the same side. So you don't make a mistake by forgetting which side you have decided to use you might consider using a black marking pen to place an arrow on each existing stud. It is perfectly ok to angle a brace so it runs at an angle from the wall to skirt obstructions. Just be sure that by running it at an angle that the brace is still long enough to extend at least 2" beyond the framing member most distant (about 6 feet) from the gable end wall. If you angle them you need not angle the end cut of the brace so that it fully butts the existing stud or retrofit stud. However you do need to make an angle cut on the Compression Block so that its end pushes against the Retrofit Stud and fully butts against the existing or the Retrofit Stud. This is so that the compression function will be fully effective.

Impediments: See section 11 for instructions for dealing with impediments.

Length of the brace: When you measure for a horizontal brace be sure that you allow 2" of extra length at the far end so the fasteners there are not too close to the end of the brace. The measurement need not be very precise as long as the horizontal brace meets the 6' minimum length and 2" beyond the last framing member requirements.

Cutting the braces: You may prefer to cut the braces outside the attic because it will probably be easier to cut there, it may also be a little easier to feed them and carry them in the attic if they are shorter. You should save the dropping (cut off section) to use as Compression Blocks. The cuts you make need not be very pretty. You may want to cut the upper brace at the same time because the length will likely be the same. In fact, while you are at it, you may want to cut all the Horizontal Braces, both lower and upper unless there is an odd one or two that need to be longer because they need to skirt an obstruction.

Fasten to framing: When you install horizontal braces onto floor framing members you may notice that some floor framing members are lower or higher than the rest resulting in the horizontal brace not making contact with one or more members. Gaps need to be filled with wood shims. Gaps tend to be more of problem with block walls than frame walls. Start installing fasteners at the wall end to help assure that the brace will be on the correct side of the

existing stud and jammed against the existing stud. Fasten to every framing member over which the brace passes. Fastening to a rafter used solely to support ceiling material, and located next to the exterior wall below, is not necessary. Nevertheless, fastening needs to be made to at least three primary framing members unless blocking or decking is used.

You will see on Figure 15 that the 3 fasteners used to secure a brace to a framing member are off set 1/2" from adjacent ones. In practice this means that one fasteners should be placed about 1/2" from the edge of the brace and about 1/2" from the edge of the framing member. The next fastener should be placed about in the middle of the brace (sideways) and about 1/2" from the other edge of the framing member as the first fastener. The third fastener should be placed in line with the first one and about 1/2" from the edge of the brace. This minimizes the chance of splitting the framing member which, because of it narrow 1-1/2" width, is susceptible to splitting. When a fastener splits wood its effectiveness will be significantly reduced. Adding more fasteners is apt to further weaken the connection instead of making it better.

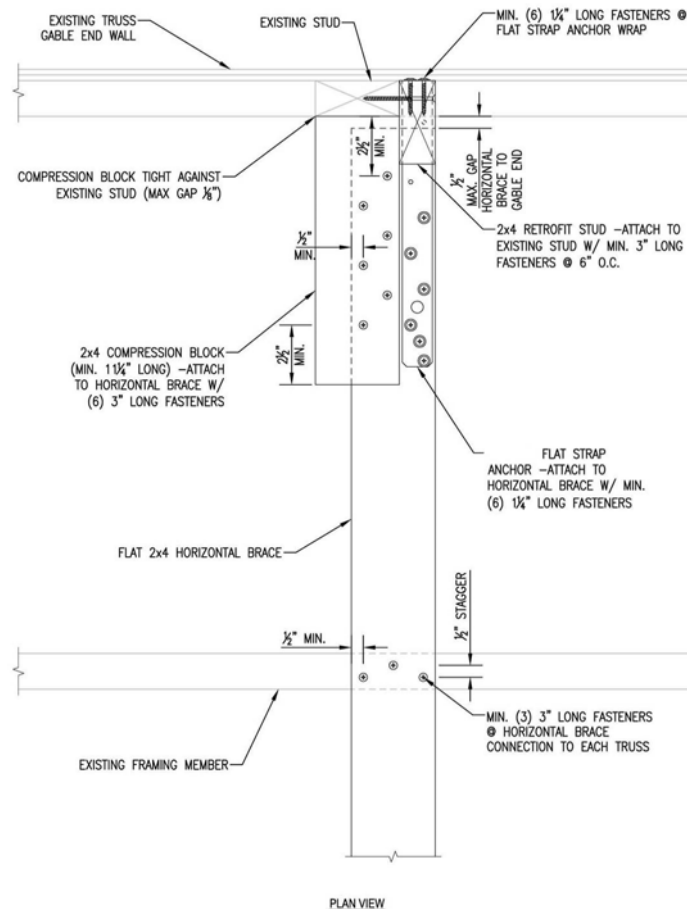


Figure 15. Layout of fasteners on horizontal brace for connection to framing members as well as connections of retrofit stud strap and one option for attachment of compression block.

If the ceiling material is drywall or plaster or other brittle or fragile finishes, screws are usually a better choice for fastening down the braces on the ceiling framing members. Installing screws produces negligible impact loads as compared to installing nails, especially when the nails are driven with a hammer.

Obstructions: A common thing you will have to deal with is wiring running over the top of ceiling framing members (Figure 16). DO NOT sandwich a wire between a brace and a framing member. That creates a fire hazard! To move a wire or to gain enough slack so that you can fish a Horizontal Brace under a wire, you may need to remove a staple or two that secures the wire to a framing member. Tools for that purpose include the claw part of a hammer, a medium sized slot (flat) screw driver, a pair of pliers, or nippers. Pull the staple up **WITHOUT** compressing the wire cable itself. Pliers and nippers should only be used to carefully grab and pry out the staple. In most cases, this is not a difficult job, just be very careful not to damage the wire or its protective cover. You can probably salvage staples for reuse. In some cases, it may be necessary to fish or needle the brace under wires as opposed to just moving the crossing point to a location that is not under the brace. You may also need to fish or needle a brace under an AC duct. Be gentle with AC ducts so as not to create costly leaks.

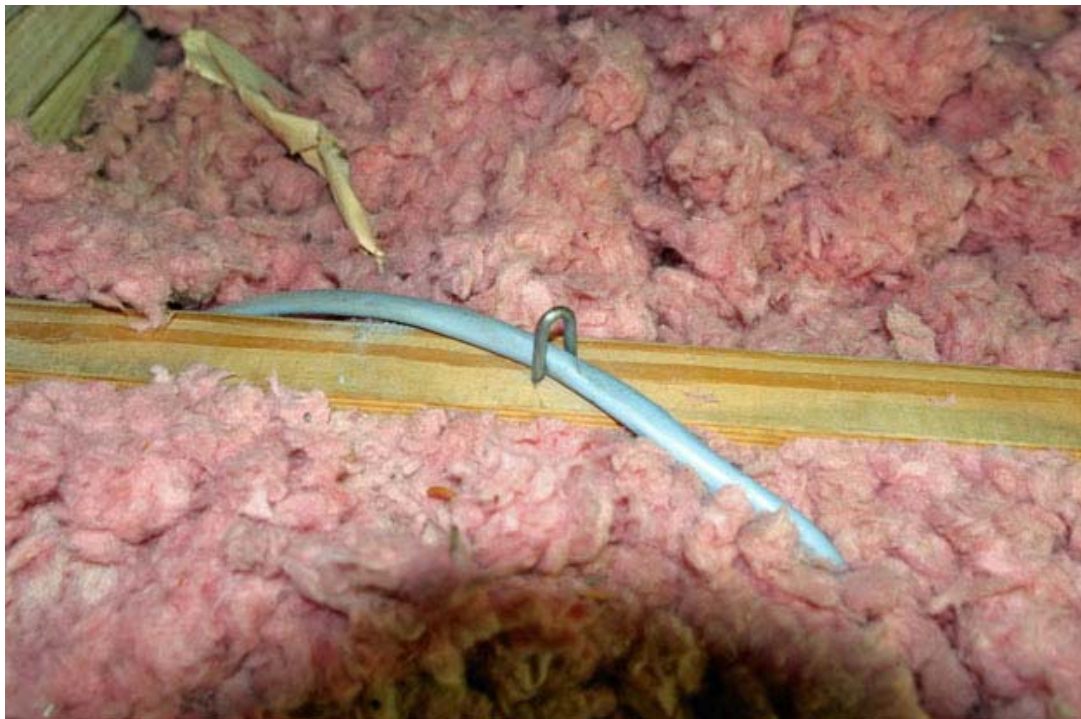


Figure 16. Electrical wiring running over ceiling joist.

Horizontal braces attached to the bottom edges of rafters or bottom edges of the top chords of trusses members:

Clearly, installing upper horizontal braces is not as easy as installing lower ones, but at least one does not have to bend over (Figure 17). It is difficult to hold a 6' brace up against the roof framing members while trying to hold it in position lengthwise, and fastening it. It seems to take 3 or 4 hands with one being at the other end 6' away. That sounds impossible, but actually is not nearly as hard as it sounds. Some hints will be offered in paragraphs below. Aside from having to hold the brace the installation procedure is the same as for the bottom brace.



Figure 17. Installation of upper horizontal brace.

Measure: The length of the upper brace will usually to be the same length as the bottom brace. It is likely that almost all the upper braces at a particular gable end will be the same length so you may prefer to cut them at the same time.

Cut: Cutting is straight forward and similar to that of the bottom braces.

Fasten to framing: Start fastening the brace at the end that butts up against the gable end wall. This will help assure that it is the right place and that it will be snug against the existing stud. Also, look down to make sure that you have positioned the brace on the same side of the existing stud where you have installed the bottom brace. If you have many gable end studs to retrofit you are apt to make the mistake of installing a brace on the wrong side of an existing stud. It is kind of dumb and waste of time, but is a mistake that most of us have made.

Hints: Hold the brace in place and mark where it crosses the roof framing member closest to the gable end and a second framing member about 4-feet farther away from the gable end wall. Start one fastener (screw or hammer driven nail) at each mark. Position yourself so that you can reach each of these fasteners and then lift the brace into place and drive the fasteners into the roof framing members starting with the fastener closest to the gable end. This will minimize the time required to hold the brace in place and allow anchoring the brace without having to hold the fasteners in addition to the brace and fastening tool. Usually one can hold the brace into place with only one hand especially if fasteners have been started, but if the brace is particularly heavy or long you may want to devise some help. One suggestion is to hang the far end from the last framing member with a rope by installing a fastener to the framing member.

Once you have installed all the lower and upper horizontal braces, you will be about one third of the way through strengthening the gable end wall.

Installing retrofit studs and strapping:

Measure: With the braces in place it is relatively easy to make accurate measurements of the required lengths for the retrofit studs. If you are going to install the retrofit stud along the taller side (side towards the roof's ridge) of the existing stud, just measure from the top of the lower horizontal brace along the edge of the existing stud up to the point where that edge lines up with the bottom of the upper horizontal brace. If you are going to install the retrofit stud along the shorter side (the side towards the eave of the roof) of the existing stud, you will need to hold the tape measure 1-1/2 inches away from the shorter edge of the existing stud and measure from the top of the horizontal brace up to the bottom of the upper horizontal brace. As an alternate, if you have figured out the slope of the roof, you can measure along the short side of the existing stud and reduce the length by multiplying the width of the retrofit stud by the slope ratio. For example, if you found that the roof slope was 5 in 12 (5 inches rise in 12 inches width or 5 feet rise in 12 feet of width) you can multiply the width of the retrofit stud (1-1/2") times 5 and divide by 12 to get a length reduction of 5/8". A snug fit at the top is preferred, but be sure to leave a little space for the bottom strap. Note that if you are installing retrofit studs on a gable truss with diagonals, you will either have to select the next size up 2x member and notch it around the diagonal or align the retrofit stud so that its narrow edge butts up against the face of the existing stud and one face of the retrofit stud lines up flush with one of the edges of the existing stud. The second alternative will allow you to attach the retrofit stud to the existing stud using mending plates.

Impediments: See section **12** for instructions on dealing with impediments and more specific guidance on installing retrofit studs on gable ends with diagonals.

Cut: Cut the stud to length. It will probably be easiest to cut a stud in the attic just after having measured for it. Then, before you install the straps, check the length by placing the retrofit stud in the desired location and make sure that it will fit snugly against the existing stud.

Bend Straps or Not. There are two issues related to bending straps. One is where to make the bend and the other is how to make the bend. Unfortunately, you can't just make the bend in the middle of the strap unless you use one that is considerably longer than you actually need. Since part of the strap wraps under the retrofit stud and you can't install fasteners in this area, you need a longer length of strap wrapping under the retrofit stud and sticking out along the horizontal brace than the length running along the back edge of the retrofit stud. Consequently, when using the strap lengths listed in Tables 1 and 5, make the bends at the locations indicated in Table 5. This will distribute the number of fastener holes in the strap at each end of the strap where the holes need to be. Ideally the bends would be nice sharp bend that are not too rounded. The other strap bending issue is that you may find it difficult to make sharp bends in heavy gauge straps without using a vise or without anything in the attic to safely bend the strap over. One suggestion is to bend them out of the attic where you can make the bends more carefully and sharper using a vise or a substitute. Another suggestion is to apply them to the retrofit stud and then bend them using a hammer to make the bend sharper. NEVER make a bend and then undo it. If a strap cannot be used because the bend is at the wrong place the strap cannot be re-bent. That weakens the strap too much. Thin straps are pretty easy to bend over the ends of retrofit studs after the straps have been fastened to retrofit studs. After bending with one's hand, a whap or two with a hammer will result in a nice sharp bend. Figure 18 illustrates the installation of the retrofit stud.



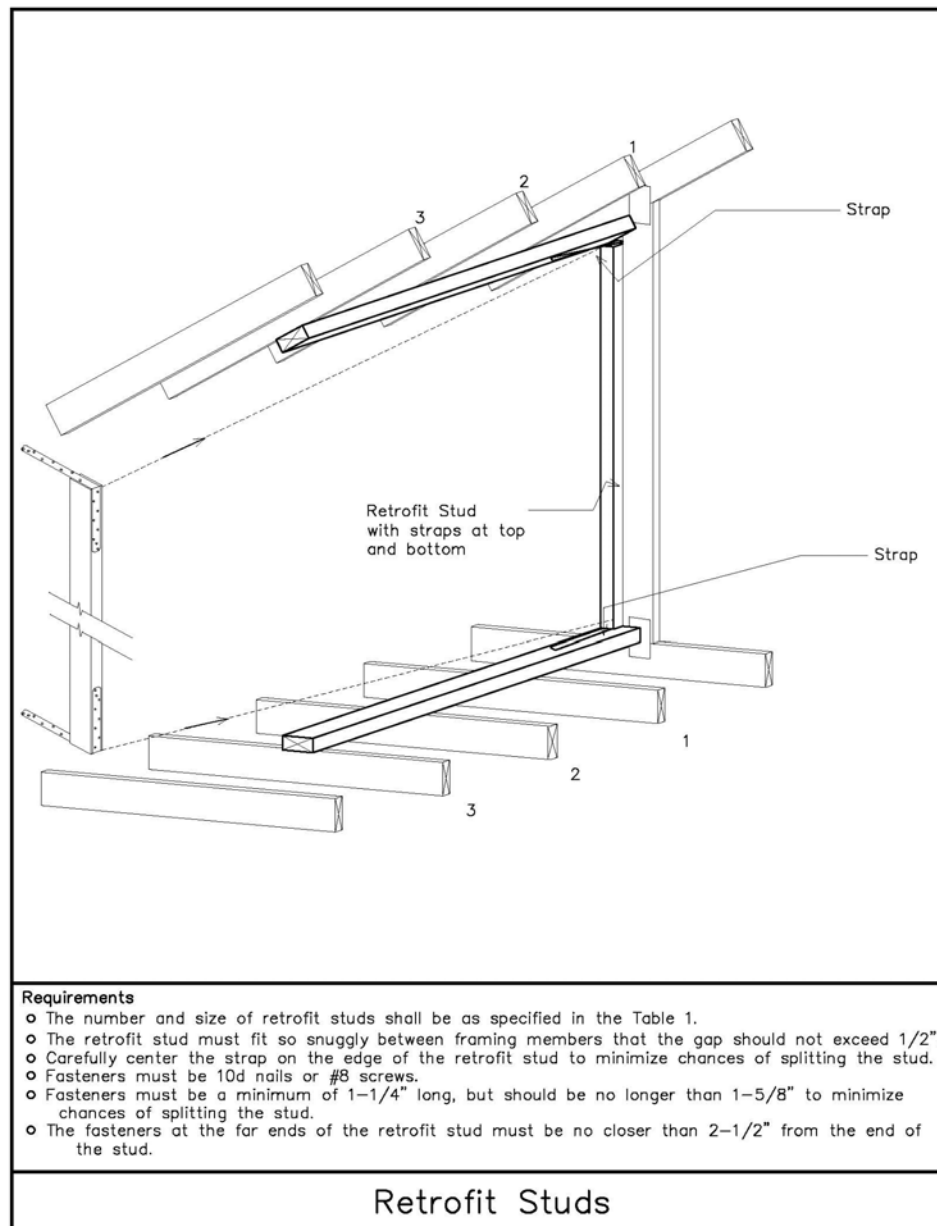


Figure 18. Installation of retrofit stud.

If you use coil strap you will have to cut it. For that you can use a good heavy duty pair of tin snips or easier yet, use a hacksaw across the flat of the strap to make a little groove and then bend the strap back and forth until it snaps. With coil strapping you will need to straighten it out somewhat and then make the bend at the appropriate length indicated in Table 5. Remember that the shorter length of the bent strap is the part that you will attach up the back of the retrofit stud and the longer portion will run under the retrofit stud and extend along the horizontal brace.

TABLE 5
Recommended Strap Lengths and
Bending Locations

Method and number of fasteners at each end from Table 1	Minimum length of flat strap from Table 1	Recommended length of flat strap Model LSTA or MSTA straps	Recommended length of coil strap Model CS16 or CS18
Method #1 6 at each end	21"	21" strap - bend at 9-1/2"; or use 24" strap & bend at 11"	21" bend at 9-1/2"
Method #2 9 at each end	30"	30" strap - bend at 13- 1/4"; or better yet use 36" strap & bend at 16-1/2"	30" bend at 13"
Method #3 12 at each end	38"	Long enough LSTA or MSTA straps are not available	38" bend at 16"
Method #4 8 on each strap at each end	30"	30" strap - bend at 12"; or use 36" strap & bend at 15"	30" bend at 13"

Notes for using the table.

1. When installing straps the key is to have at least the minimum number of fasteners installed at each end in accordance with the first column of the table.
2. The bend location is in relation to the stud (not brace) end of the strap. The short leg of a bent strap always goes on the retrofit stud.
3. Where a strap is cut compared to where the holes are makes a difference, but the worst case is taken into account in specifying both the needed minimum of length strap and the bend location.
4. Some manufacturers of connectors and straps add 'Z' to the end of the model to indicate that the connector is more rust resistant. This is probably not important for straps in attics, but of course it does no harm.
5. Fasteners should not be placed closer than 2-1/2" from the end of a retrofit stud.

Install the straps: Select one of the 1-1/2" wide edges of the retrofit stud and install a strap at each end of the retrofit stud. If you have pre-bent the strap, make sure that it is oriented such that the bent leg wraps across the end of the stud as shown in Figure 18. When fastening the strap to the 1-1/2" edge of the stud, it is important that every fastener required by the table is installed and that the strap is centered on the edge of the retrofit stud. There are two critical distances that need to be respected to achieve the full strength of the connection. One is the edge distance between a fastener and the edge of the retrofit stud. That distances needs to be no less than 3/8".

Placement of the strap in the middle of the 1-1/2" edge of the stud is very critical because the placement of holes in commonly available straps results in the holes being exactly 3/8" from the edge. Installing a fastener closer than 3/8" to the edge of the stud reduces its effectiveness. Installing the fastener too close to the edge can create a split along the edge which would make those fasteners almost completely ineffective. To minimize the chance of splitting it is suggested that fasteners be installed at an angle towards the center of the stud. This will keep most of the fastener away from the edge. The other critical distance is that no fasteners should be closer to the end of a retrofit stud than 2-1/2".

Stud-to-stud connection: Now you are ready to connect the retrofit stud to the existing stud. This will tie the two together so that you double or more than double the strength of the existing stud. To do this you need to place 3" fasteners no more than 6" apart along the length of the retrofit stud. If the existing stud has its wide face parallel to the gable end wall (truss stud) then install the fasteners through the back portion of the retrofit stud and into the middle of the 1-1/2" edge of the existing stud. Keep the top and bottom fasteners at least 2-1/2" from the ends of the retrofit stud in order to minimize chances of splitting the end of the retrofit stud and to make the fastener fully effective when it is stressed by wind loads. The retrofit stud and existing stud combination will increase the strength of the wall and help it resist the wind forces pushing or pulling on the wall. Its effectiveness will be limited in the pull mode unless the wall sheathing is well attached to the existing stud. In homes built prior to 2002 it is likely that the attachment is not adequate. If your gable end wall has plywood siding on it you may be able to spot the nail heads from outside the house and be able to check the nail spacing. Ideally the nails would be on average 6" or less apart.

Applying construction adhesive to the 1-1/2" edge of the retrofit that will be in contact with the sheathing will help restrain the sheathing from getting pulled off (Figure 19). Applying a bead of construction adhesive along the edge of the existing stud where it meets the sheathing on the opposite side from where the retrofit stud is to be installed will help as well. It is not known how many years construction adhesive will be effective in hot attics, but it is so easy and inexpensive to do that one can hardly go wrong. Be warned that some people may find the fumes offensive, but in a hot attic they will dramatically dissipate in a day or two. There is more information about using construction adhesive in Section 14.

Where you want to push a retrofit stud into place, you may well find nails or staples coming through the siding that prevent pushing the stud against the siding. You may be able to bend (clinch) them against the sheathing/siding or you may be able to snip them off with a pair of nippers or wire cutters. In any case it is ok if the retrofit stud is as far as 1/4 inch from the siding. It will still be just as effective. However, if the distance can be kept short then you can gain the important structural advantage of being to apply construction adhesive to help hold the wall sheathing/siding onto the wall.



Figure 19. Applying construction adhesive where retrofit stud will make contact with the sheathing

Installing straps on braces: Once the retrofit stud is securely fastened to the existing stud, you are left with the easy task of securing the straps coming from top and bottom of the retrofit stud to the two horizontal braces. The only heads up issue is to route the strap along the horizontal

brace, away from the edge of the brace, so that you maintain an edge distance of least 1/2" between the fasteners and the edge of the brace.

Installation of compression blocks:

Installing compression blocks is the easy final step. The lengths specified in the table are minimum lengths so it is perfectly ok to use scraps (droppings) of 2x4s, 2x6's, or 2x8's that are longer without having to cut them to precise lengths. The minimum size for lumber used as blocking is a 2x4. A key issue with compression blocks is to butt them snugly against the retrofit studs so they can act in compression with minimum movement of the wall studs. Another key issue is to be sure you install all of the fasteners so they are fully effective. That means positioning them a minimum of 1/2" from the edge of the block and horizontal brace, at least 2-1/2" apart along the length of the block, and a minimum of 1" apart in the cross block direction (across the grain). Depending on how the strap runs on the horizontal brace you may need longer compression blocks in order to maintain the fastener spacing requirements.

With the installation of compression blocks complete you are finished with the gable end retrofit. That leaves only the wall-to-wall connection, unless you have already done it.

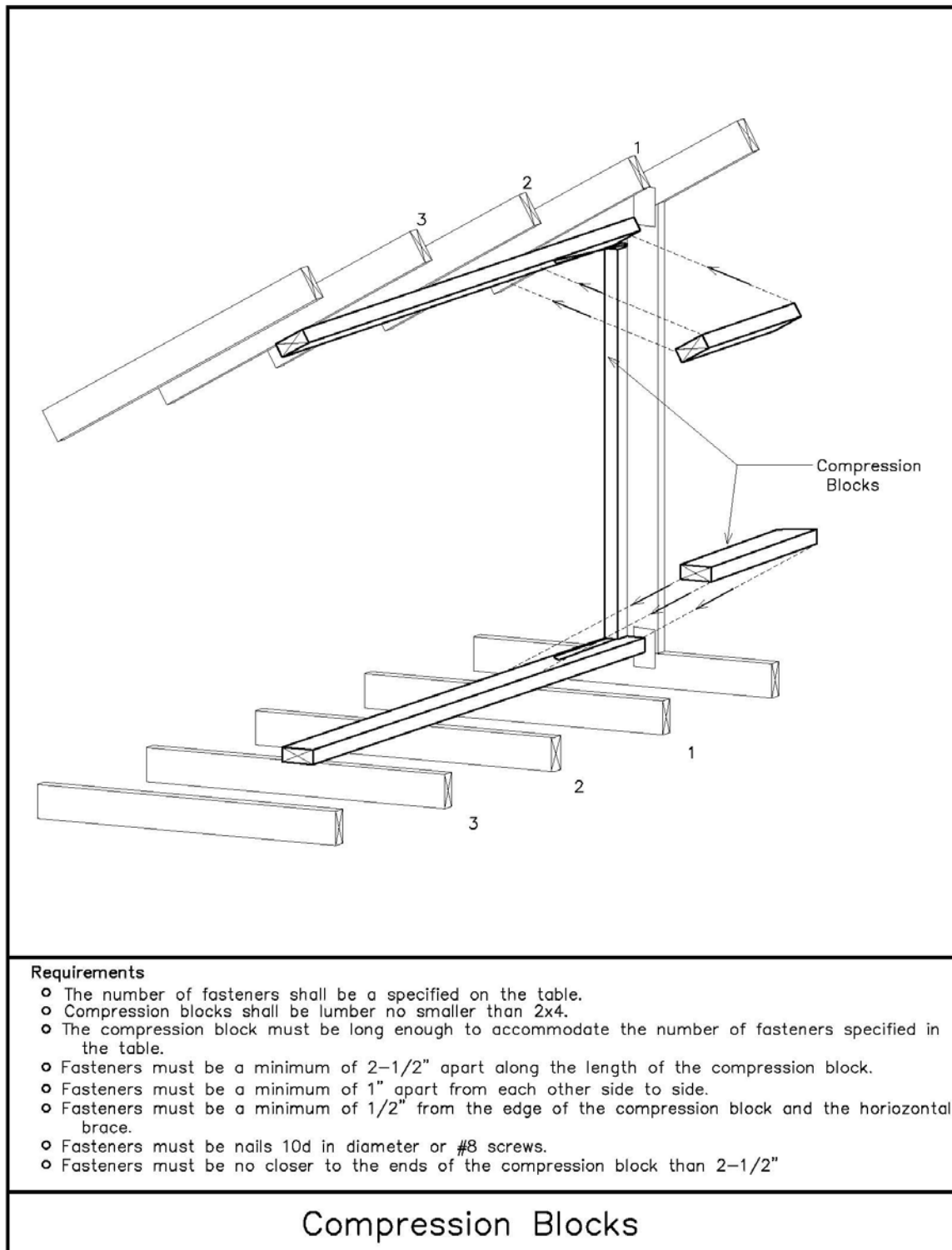


Figure 20. Installation of compression blocks.

10.0 Strengthening the wall-to-wall connection

In Figures 12 or 13 (**Section 5**) you will likely find a sketch that shows how your gable end walls rest on the walls below. Some houses have lower walls made of wood frame (Figure 12) and others have walls made of concrete block (Figure 13). In either case it is likely that the lower walls are not well restrained from moving in or out under the pressures created by hurricane winds. Exceptions would include homes built to the requirements of the 2003 International Building Code or homes built in the 1990's if your community was enforcing the high wind provisions of the Standard Building Code. This is true even if the walls are made of concrete block.

The goal of strengthening the wall-to-wall connection is to help restrain the lower wall from moving in or out by tying the top of that lower wall to the strengthened gable end wall. It may seem strange that the upper wall could help hold the lower one. However, the strengthening occurs because the upper retrofitted gable wall is tied back at least 6' into the interior roof structure where forces can be dissipated over the roof and ceiling planes. To a lay person this may not seem significant, but engineers readily understand its effectiveness.

Houses with wood frame lower walls: Figures 12a through 12c show truss type gable end walls resting on conventional wood frame lower walls and Figure 12d shows conventionally framed gable end walls resting on conventional wood frame lower walls. If your initial inspection of your roof framing led you to brace your gable end, it is a safe and reasonable assumption that the two walls are also not sufficiently connected together. This means that you need to select the method from that will work for your case. The methods are really quite straight forward and easy to implement. Simply follow the fastening instructions provided by the manufacturer for the connectors you choose to use. You can substitute #8x1-1/4" screws for 1-1/2" nails; and #8x3" screws for 10d nails. If right angle gusset brackets are selected for the connection, then use Table 2 to give you the maximum spacing of the brackets. If you use SP1 type connectors, then connections need to be made at either every existing stud or retrofit stud location. It is frequently difficult to get more than two fasteners on each side of one of the right angle gusset brackets to line up away from an edge of the structural members. The spacing has been worked out assuming that only two of the fasteners are properly engaged. Consequently make sure that at least two of the fasteners are centered up on the middle portion of the framing lumber, away from an edge.

If you use right angle gusset brackets it is strongly suggested that you connect all the plates at the top of the bottom wall together by using four 4-1/2" screws for securing the bottom part of the bracket instead of the 3' screws provided by the manufacturer. Typically the two top plates of the bottom wall are not connected together very well and the siding on the outside of the wall

probably does not serve that function well enough either. The longer screws will connect the plates thus substantially helping to connect the parts of the walls. Look in Figure 12 for your wall configuration and if there are three layers of wood, use the 4-1/2" long fasteners.

House with concrete or concrete block lower walls: First determine how the gable end wall (truss or conventionally frame) rests on the block wall below. If the block wall has a 2x8 on it, it is likely that the 2x8 is not adequately connected to the wall below. The 2x8 can be regarded as adequately connected if all of the following conditions are met:

- 1) If it has 1/2" diameter anchor bolts spaced no farther apart than 48" in which the 2x8 has not been gouged or chiseled out so the washer and nut could be installed,
- 2) If the bolt does not protrude more than 1-1/2" above the top of the 2x8,
- 3) If there is an anchor bolt within 12" of the end of the 2x8 and there is an anchor bolt within 12" of an existing or retrofit stud, and
- 4) If a washer is in place.

Otherwise if all of these conditions are not met the 2x8 should be considered inadequately anchored. In that case there are two alternatives. One is to anchor the 2x8 better and proceed with attaching the gable end wall to the 2x8. The second is to disregard the connection between the 2x8 and the wall by making your retrofit connections through it and directly into the concrete below. You can pretty easily anchor it better simply by adding 1/4" diameter masonry screws that penetrate at least 1-3/4" into the concrete poured in the cell of the block. One such fastener should be placed within 12" of each existing or retrofit stud.

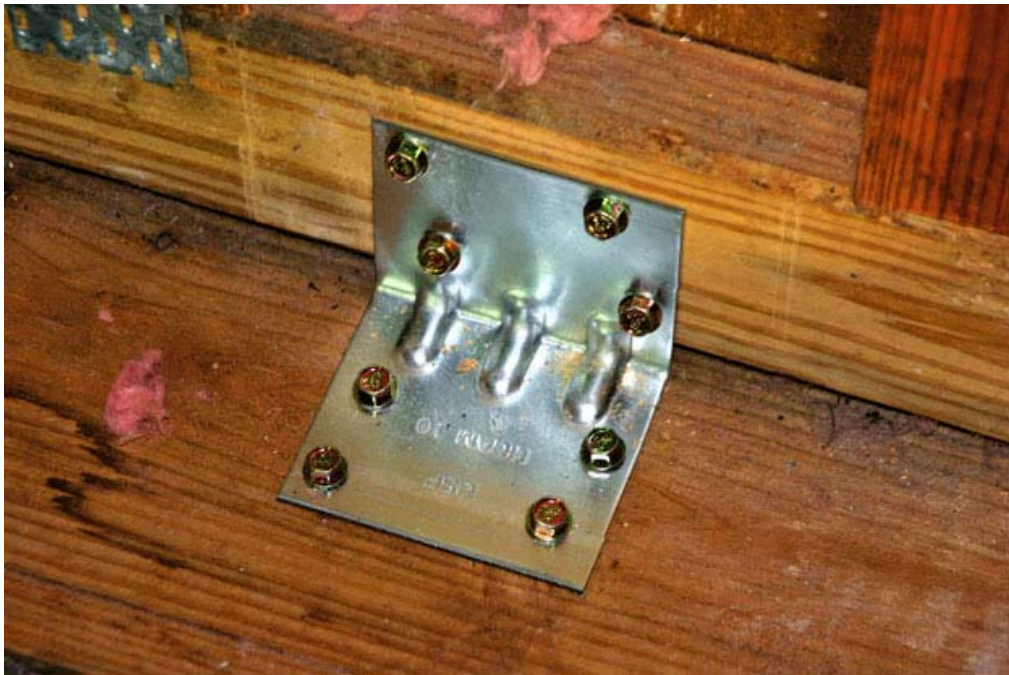


Figure 21. Right angle gusset bracket installed to tie gable truss bottom chord to 2x8 on top of masonry wall.

Final check: Before you leave the gable end it would be a good idea to insure that you did not forget to install some fasteners. Ones that sometimes get overlooked are those in horizontal braces so look each brace over to insure that you did not skip attaching it to a framing member. Check that you have not left any tools or stashes of parts such as fasteners. Then reset batt or blown insulation and fluff up blown insulation. When you have finished retrofitting the gable end you should be pleased with yourself for having strengthened your house in a permanent and effective way that makes your house both stronger and safer.

11.0 Impediments to the installation of Horizontal Braces

Skirtable Impediments: In many instances impediments such as recessed lights, AC ducts or ceiling supplies or inlets, bathroom exhaust fans, etc. can simply be skirted by installing a horizontal brace at an angle. There is no functional harm in doing this. The key is to be sure that the brace is still long enough so that the fasteners to the framing member at the far end of the brace from the gable wall are at least 2-1/2" from the end of the brace.

Fishing horizontal braces: There may be a wire or an air conditioning duct in the way that requires you fish a horizontal brace under the obstruction. This requires that there is enough space to maneuver the horizontal brace and enough clearance. There needs to be a gap of at least 1-1/2" in order for the 2-by horizontal brace to slip under the obstruction.

Splicing horizontal braces (above): If there is not enough space to fish a full 6' long brace under an obstacle (probably because of other obstacles), then the brace can be spliced as long as it is done effectively. The basic rule is that each side of the splice has to have the total number of fasteners to be applied in any framing members beyond the splice (measured away from the gable end). For example, if the splice is made between the first and second framing member away from the gable end, then the part beyond the splice would cross two framing members and would have a total of six fasteners. Consequently, six fasteners would be required between the horizontal brace and the splice block on both side of the splice.

Splicing horizontal braces (below): If an obstruction is so close to the top of framing members that installing a horizontal brace is not possible, then it may be possible that a splice can be made under braces in a manner similar to that just described.

Thinner horizontal bracing: If a 2-by horizontal brace can't be fished under an obstruction, but plywood 1/2" or thicker will fit, then a solution is to use a 1' to 2' wide strip of plywood that is as thick as possible and long enough to span three framing members. Attach the plywood with 1-1/2" long #8 screws at a 5" to 6" spacing along each framing member crossed. Similarly, if an obstruction prevents you from running a horizontal brace 4' from the gable end (see 4' blocking below) then you can use plywood running parallel to the gable end and spanning across adjacent horizontal braces to help distribute the wind loads into the ceiling or roof structure. Make the plywood strip as wide as possible and anchor it to all of the horizontal braces that it crosses including the short one installed at the obstruction with 1-1/2" long #8 screws at 5" to 6" spacing.

Four foot long horizontal braces: If 6' long horizontal braces can't be installed but 4' or longer braces that rest on 2 interior framing members can be installed, then blocking can be used to safely transfer the loads. Figure A -11 shows a remedial method that can be used in this situation. The essence of it is the installation of a block of the same depth as the framing members. By depth is meant the larger face of the framing member and not the 1-1/2" edge. The anchor block helps transfer the load that a retrofit stud applies to a horizontal brace to the plane of the ceiling. The figure makes it pretty clear how the block is to be installed. It is important for the block to function effectively that it be pretty precisely cut so there is little gap between it and the framing members. The gap should be limited to 1/8" at each end. The anchor block also helps prevent framing members from twisting.

Obstructions that prevent installation of 4' long horizontal braces or sheathing (see thinner horizontal braces above): Where there are obstructions that prevent installation of 4' long horizontal braces that rest on at least two framing members interior to the gable end wall and a plywood strip at least 1 ft wide can not be installed parallel to the gable wall as described above, then a retrofit stud cannot be installed because it would not be secured at one end. In that case read the next section about impediments to the installation of retrofit studs. What needs to be done to compensate for the missing retrofit stud is to strengthen the retrofit studs on each side of the missed one and to build a ladder between the two that spans over the missed retrofit stud.

Truss plates: Where truss webs are attached their plates may prevent installation of horizontal braces onto framing members precisely where they would ordinarily be placed. In the typical case where the plate is at the peak, the method shown in Figure A - 15 can be used.

12.0 Impediments to the installation of Retrofit Studs

Do not get discouraged if you cannot install a retrofit stud every place one is required in the straightforward procedure. The methods suggested in this section and the preceding one ought to allow installation of most of the retrofit studs needed or provide an alternative means of achieving the strengthening you are seeking.

Splicing retrofit studs or Can't get long enough retrofit studs into attic: When retrofit studs need to be spliced the method shown in Figure A - 12 can be used. Notice that this method requires 54 (2 times 27) fasteners to secure the splice member so it might be easier to make more effort to fish a sufficiently long retrofit stud into the attic to preclude the need for a splice.

Single missed retrofit stud: Where a single retrofit stud cannot effectively be installed and it is not the last one before the height drops to less than 3', then the way to compensate for the missing stud is to make the retrofit studs on each side stronger and install 2x4s horizontally between them that are spaced 12" apart vertically. The horizontal 2x4s are secured using h-ties at their ends to the retrofit studs and to the 'missed' existing stud. See Figures A - 13 and A - 14. The shape is not unlike a ladder. The directions for this solution are limited to a single missed retrofit stud and there have to be at least two successfully installed retrofit studs between any missed retrofit studs. This prevents doubling up the loading on a single retrofit stud, albeit a larger one than normally required. It is certainly possible to increase member sizes and span greater distances, but the engineering has not been worked out and it is expected to be fairly rare that the solutions presented here can not be made to work.

Truss Webs - Can't install retrofit stud to edge or face of an existing stud: Truss webs are the most common reason one cannot install retrofit studs in the usual manners. The work around for this is to increase the strength of the retrofitting by increasing the method one step, for example from method #1 to 2, or 2 to 3, or 3 to 4. If the method is already #4, then that is about all one can do without getting professional help from an engineer. The existing stud and stronger retrofit stud can be connected using 4" to 6" long mending plates (metal plates with many holes made for joining wood, much like truss plates) spaced every 12" along the length of the studs.

Retrofit studs longer than Table 1 allows: Gable ends higher than 16' most likely are made of two trusses with one over another. Such trusses are called piggy back trusses with each member not being much higher than 8'. Such high trusses should be evaluated by an engineer to determine retrofit measures. The engineer might regard the two trusses as separate entities by calling for retrofitting them individually while providing additional measures where the two meet by extending horizontal braces into the interior. Taking photographs of the gable end will help the engineer to understand the gable end situation before the engineer visits the attic.

Retrofit studs that need to be notched: If there are obstructions such as diagonal truss webs or pipes running horizontally, then the studs can be notched around them. The very important issue is that the retrofit stud be left with enough depth at the notch that it meets the depth requirement of row number 3 in Table 1.

13.0 Work arounds and dealing with atypical situations

Gables of odd shapes Gables of odd shapes really don't affect the method of retrofitting as long as the methods described in Section 9 can be used. If a gable end is chopped off for some reason then there is just that much less that one needs to retrofit. A common situation on many houses is where one gable end dies into another gable. The outermost/farthest one can be retrofitted as usual whereas the combination one may be more difficult. However, if the existing studs that span from the roof down to another roof or to roof of the smaller gable are no longer than 3' then they don't need to be retrofitted even if the total length is longer. This is because it is the distance between supports that is critical. Where that difference is 3' or greater then some sort of retrofitting is needed. If a method does not occur to you for doing this you should consider getting professional guidance.

Major obstructions: See the section above about major obstructions to horizontal braces.

14.0 Other retrofits to reduce risks of damage and water intrusion at gable ends

Gable vents: Vents at gable ends frequently let rain driven by strong winds into the attic and hurricanes often force winds will drive catastrophic amounts of rain into the attic. This is because there is no known practical way to separate wind driven rain from wind. Hurricanes produce strong winds and sometimes they produce such winds for hours at a time. There is no known method of louvers or baffles that will keep enough water out of an attic during a sustained wind driven rain event (strong hurricane) to prevent substantial damage. Evidence of water coming in gable end vents has as been observed to have occurred in every hurricane when the winds were very strong. It is best to block gable end vents off from the outside to minimize chances of water getting into the wall that can lead to mold in the walls or even water getting inside the house. Shutters cut to size, plywood or vinyl coated fabric storm panels can be used to block from entering through the gable end vents.

Water intrusion: Any place you can see light coming into an attic it is almost a certainty that water blown by a hurricane can come in as well. Note the use of the 'any' in the preceding sentence. It was used literally, any. Soffits at gable ends where the gable end truss is below the roof sheathing 4" have been demonstrated by numerous hurricanes to allow damaging amounts of water into an attic. Yes, they are under the overhang roof, yet strong winds can easily drive rain very nearly horizontally and even upwards to penetrate any hole in the wall. Other sections of the web based Hurricane Retrofit Guide discuss remedial measures you can and should take.

Gable end siding: The siding on the gable end is very important in protecting your house. If it was not very strong to begin with, deteriorated by rot, water damaged, or has delaminated, or is not adequately fastened, then you need to consider siding retrofit measures.

Overhang and outlookers: Overhangs and outlookers at gable ends are sort of like sore thumbs sticking out to catch wind and consequentially peeling off roof sheathing. Typically they are under designed for the pressures they are exposed to. Some of them lend themselves to strengthening. The web based retrofit guide provides some directions for anchoring the outlookers. If you have them, check out those recommendations. You need to strap them down where they cross the gable end and also restrain the end that butts up against the second truss or rafter.

15.0 Inspection guide and planning tools

===== SHOPPING LIST FOR GABLE END WALL STRENGTHENING =====

Lumber

Size and length	For method	Function
2x4x8' #2 SPF	All	Horizontal Braces
2x4x8' #2 SPF	#2	Retrofit Studs
2x6x10' #2 SPF	#2	Retrofit Studs
2x6x12' #2 SPF	#2	Retrofit Studs
2x8x 12' #2 SPF	#3 and #4	Retrofit Studs
2x8x 14' #2 SPF	#3 and #4	Retrofit Studs
2x8x 16' #2 SPF	#3 and #4	Retrofit Studs

Selecting lengths of lumber: #2 or better means #2, #1 or Select, but NOT #3 or stud grade

SPF means Spruce Pine Fir. SYP means Southern Yellow Pine, SP means Southern Pine. Pine is stronger than SPF, but is harder and heavier. Harder makes it stronger, but harder to drive screws or nails into. Heavier makes it more difficult to carry in an attic. The extra strength is not necessary, but of course does not hurt.

Straps

For method	Strap (LSTA or MSTA). Simpson or USP	Number needed per Retrofit Stud location	Number of Retrofit Stud locations	Number to purchase
#1	21" or 24"	2		
#2	30" or 36"	2		
#4	36"	4		
#3	15" or 18"	2 or coil		
#3	36"	2 or coil		
#3	Simpson CS18R or USP RS18-R. 25' coils	2 pieces 38" long		
All (optional use of coil)	Simpson CS18R or USP RS18-R. 25' coils			

Fasteners

Fastener Length	Length of gable end	Estimated number for length of gable end	Screws per pound	Nails per pound 1-1/2" 10d * / 10d common	#8Screws to purchase (square head drive are recommended)	Nails to purchase
1-1/4"	24'	220	156	100		-----
1-1/4"	32'	264	156	100		-----
1-1/4"	40'	396	156	100		-----
3"	20'	261	69	70		
3"	32'	319	69	70		
3"	40'	462	69	70		

The numbers assume the roof pitch is 6/12. If it is steeper more fasteners will need to be added especially for wider gable ends.

* A common designation for 1-1/2" 10d nails is N10. They are available at places that sell connectors such as Simpson and USP.

1/4" diameter by 4-1/2" long wood screw fasteners

Masonry screws

Tapcon, Powers, Simpson Titen,

Mending plates

Tools you may not have

Wire cutters, nippers

===== SHOPPING LIST FOR WALL-TO-WALL CONNECTIONS =====

Special order items

Right angle gusset brackets HGA10KT. (The Number of kits order _____)

HGAM10KT. Number of kits to order _____

Off the shelf items

1/4" x 4-1/2" wood screws. Lag bolts, Simpson SDS25412, USP WA450

4 are needed for HGA where there are 3 2x4s to go through. Some may be needed to tie walls.....Number needed _____

Connectors

H2.5 or

SP1 or SPT22

Fasteners

Screws: #8 x 1-1/4"

Screws: #8 x 3"

Nails: 8d or 10d 1-1/2", e.g. N8 or NA8 or NA11 or N10 or NA9 or NA10

10d _____

Nails: 10d common (0.148 diameter and 3" long) _____

Screws: 1/4" X 4 1/2" wood screws (Simpson SDS, USP xxx, lag bolts)

Washers for 1/4" bolts

Washers for 1/2" bolts

Note: Model numbers are suggestive only and are given for several brands.

===== **SHOPPING LIST FOR LADDERS (MISSED RETROFIT STUDS)** =====

Connectors

H2.5

Simpson A21

Lumber

2x4x8' No 2 SPF for the ladder. Reminder: 4' long ladder pieces may not be long enough depending on the sides of the existing studs the retrofit studs will be applied to.

Retrofit studs. Reminder: Retrofit studs will need to be the next larger than what would otherwise be used.

Fasteners

#8 x 1-1/4" screws

#8 x 3" screws

N10

10d

1/4" X 4 1/2" wood screws (Simpson SDS, USP xxx, lag bolts)

Washers for 1/2" bolts

ATTIC INSPECTION CHECKLIST

Checklist of things to take into the attic

1. Print the Wall-to-Wall Connection Details figure so you can use it as a guide to what you may find.
2. Print the Sample Sketch Page
3. Print one or more copies of the Sketch Page, at least one for each gable end. Taking more than one page up for each gable end will be helpful so the sketch does not get too cluttered.
4. Tape measure
5. Flashlight (battery halogen is ideal) or other lighting
6. Pad of paper for making notes
7. Pen for taking notes
8. Digital camera, if you have one.

Observations in the attic

Gable end location on house. [Front], [Back], [Left], [Right], _____

First: General observations

101. Roof system. Circle one [Truss] or [Rafters/ceiling joists]

(Trussed gable ends have studs flat wise to the wall. Trusses have metal plates connecting the component pieces of lumber together. Usually the lumber is 2x4 except that sometimes the top one will be 2x6 or bigger.)

(Rafted gable ends have studs with their edges to the wall. Rafters are usually bigger than 2x4s. Rafters usually have collar ties, i.e. horizontal 1x4s or 2x4s that run between rafters on opposite side of the peak and are located within a few feet of the peak. There may be diagonal members that connect rafters and ceiling joists. Most likely they will not be attached with metal plates, but instead just with nails.

102. Studs: [Flat face against the gable end wall] or [Edge of stud against wall]

103. If truss, circle one [just studs and no diagonal members] or [studs and diagonal members]

104. Stud spacing. Circle one: 16", 24", 32", 48"

105. Are there two sets of studs on a truss gable end? Yes/No. Describe.

Second step: Sketch in general information

201. Sketch in each existing stud that is 3' or longer. The precise locations are not important

202. For each existing stud that is 3' or longer measure its length ===methodology ===

203. If webs are present on truss sketch them. Approximate locations are good enough.

204. It is optional to note the slope of the roof. Slope: _____ : 12 or _____ vertically by _____ horizontally

Third step: Sketch information about feasibility of installing retrofit studs

301. For each existing stud determine if retrofit studs can be installed. If because of an impediment place an 'X' on the side or sides that prevents installation of a retrofit stud. Note the reason, e.g. electrical pipe, plumbing pipe, bathroom exhaust pipe.

302. If an existing stud is not full length because it has been interrupted make a note of that and the reason for the interruption, e.g. gable end vent

Fourth step: Sketch information about feasibility of installing horizontal braces

At each location where studs are 3' or longer look for obstructions and impediments. The Sample Sketch suggests ways of making your sketch and of taking notes.

401. At each location draw in a diagonal line to represent each horizontal brace top and bottom.

402. Evaluate whether a horizontal brace can be installed that is 6-feet plus long

403. If a 6' Horizontal Brace can not be installed can a brace that is 4-feet long be installed? If yes, then circle:

The size of floor framing members (joists or truss bottom cords) 2x4, 2x6, 2x8, 2x10, 2x12

The size of ceiling framing members (rafter or truss top cords) 2x4, 2x6, 2x8, 2x10, 2x12

404. If the horizontal brace will have to be less than 4-feet long, how long can it be and can you install a piece of plywood decking that would span across the short brace and reach to longer braces on either side? How long can the brace be? ____ inches. Can plywood decking be added? Yes? No?

Fifth step: Wall-to-Wall connection observations

501. Lower wall: Observe construction of wall below. Find the drawings on **Figure 101 and 201** that closely matches what you see.

502. Upper wall. Observe the construction of the gable end wall above. Find a drawing found in the previous step that best reflects what you see. Circle it.

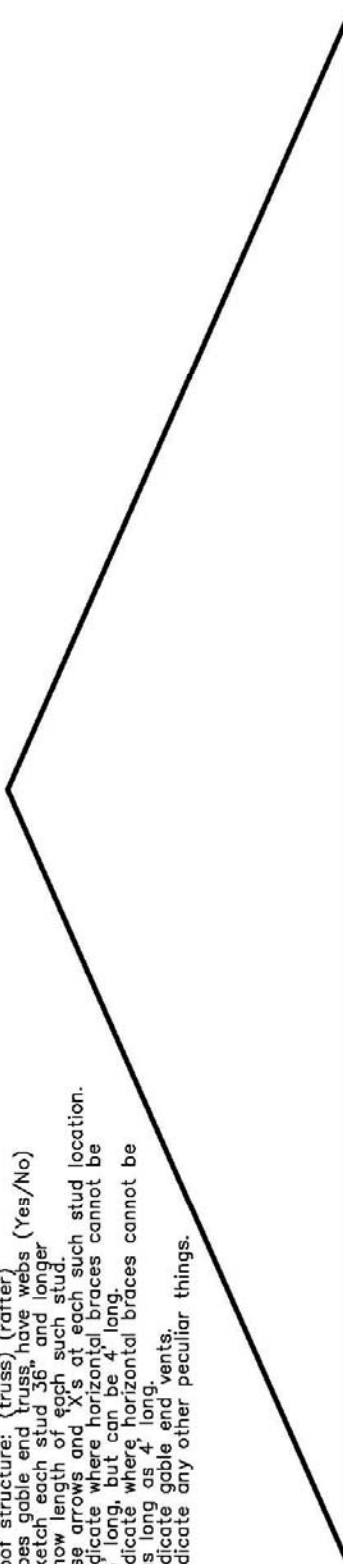
503. Take photos to show and remind you of what you see.

504. Note and photograph any existing fastening between the gable end wall and the wall below.

Attic observations				From Table 1				From Table 1								
Stud Num.	Side	Existing stud length	# of Horiz. Braces	1 or 2 Retrofitted Studs	Retrofitted Stud 2x4 2x6 2x8 2-2x8	Strap Length fasteners	Strap # fasteners	Compression Blk # fasteners	Side	Existing stud length	# of Horiz. Braces	1 or 2 Retrofitted Studs	Retrofitted Stud 2x4 2x6 2x8 2-2x8	Strap Length fasteners	Strap # fasteners	Compression Blk # fasteners
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
Totals -->																

Checklist for Sketch

1. Roof structure: (truss) (rafter)
2. Does gable end truss have webs (Yes/No)
3. Sketch each stud 36" and longer
4. Show length of each such stud.
5. Use arrows and 'X's at each stud location.
6. Indicate where horizontal braces cannot be 6' long, but can be 4' long.
7. Indicate where horizontal braces cannot be as long as 4' long.
8. Indicate gable end vents.
9. Indicate any other peculiar things.

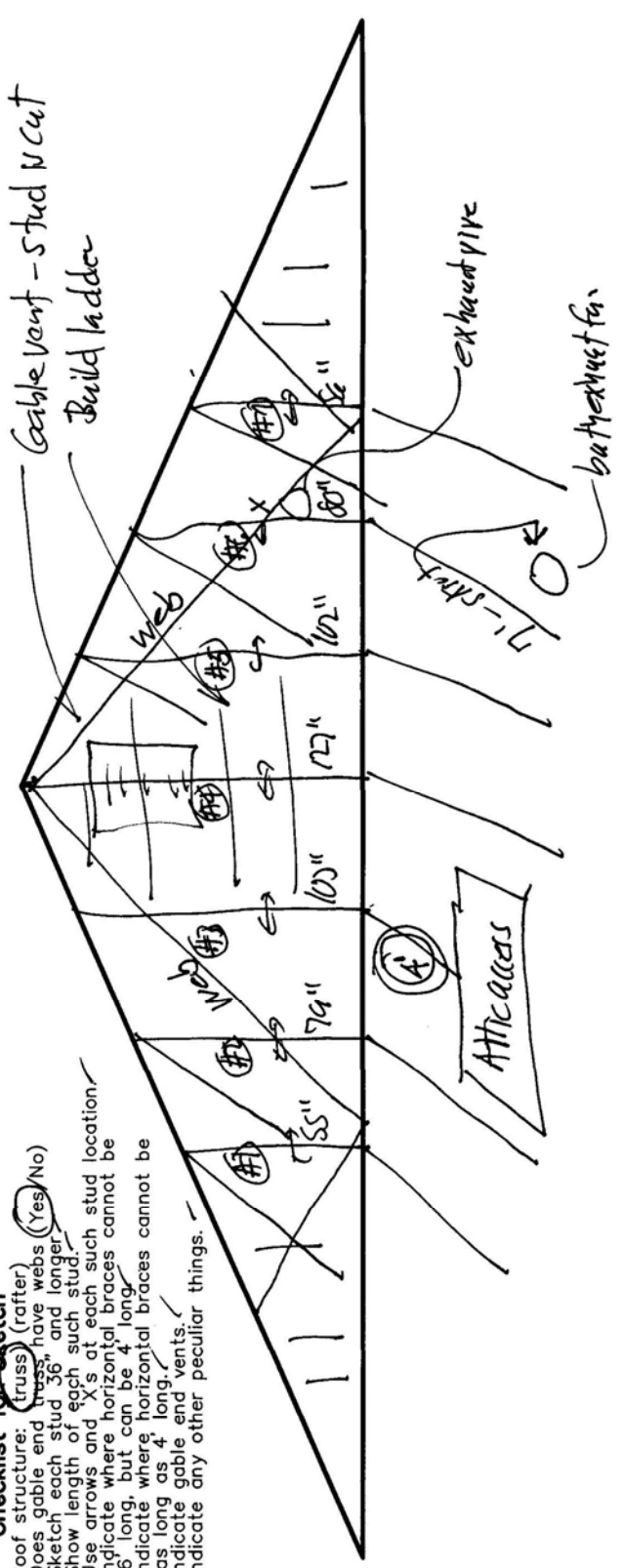


Attic observations				From Table 1				From Table 1		From Table 1	
Stud Num.	Side	Existing stud length	# of Horiz. Braces	1 or 2 Retrofits Studs	Retrofit 2x4 2x6 2x8 12-2x8	Strap Length fasteners	Strap #	Compression Blk #	Length fasteners	Length fasteners	Length fasteners
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
Totals -->											

Attic observations				From Table 1				From Table 1		From Table 1	
Stud Num.	Side	Existing stud length	# of Horiz. Braces	1 or 2 Retrofits Studs	Retrofit 2x4 2x6 2x8 12-2x8	Strap Length fasteners	Strap #	Compression Blk #	Length fasteners	Length fasteners	Length fasteners
1		55									
2		79									
3		102									
4		121									
5		102									
6		X 80									
7		56									
8											
9											
10											
11											
12											
Totals -->											

Checklist for Sketch

- Roof structure: (truss) (rafter)
- Does gable end have webs? (Yes/No)
- Sketch each stud 36" and longer.
- Show length of each such stud.
- Use arrows and X's at each such stud location.
- Indicate where horizontal braces cannot be 6' long, but can be 4' long.
- Indicate where horizontal braces cannot be as long as 4' long.
- Indicate gable end vents.
- Indicate any other peculiar things.



Right Side Gable

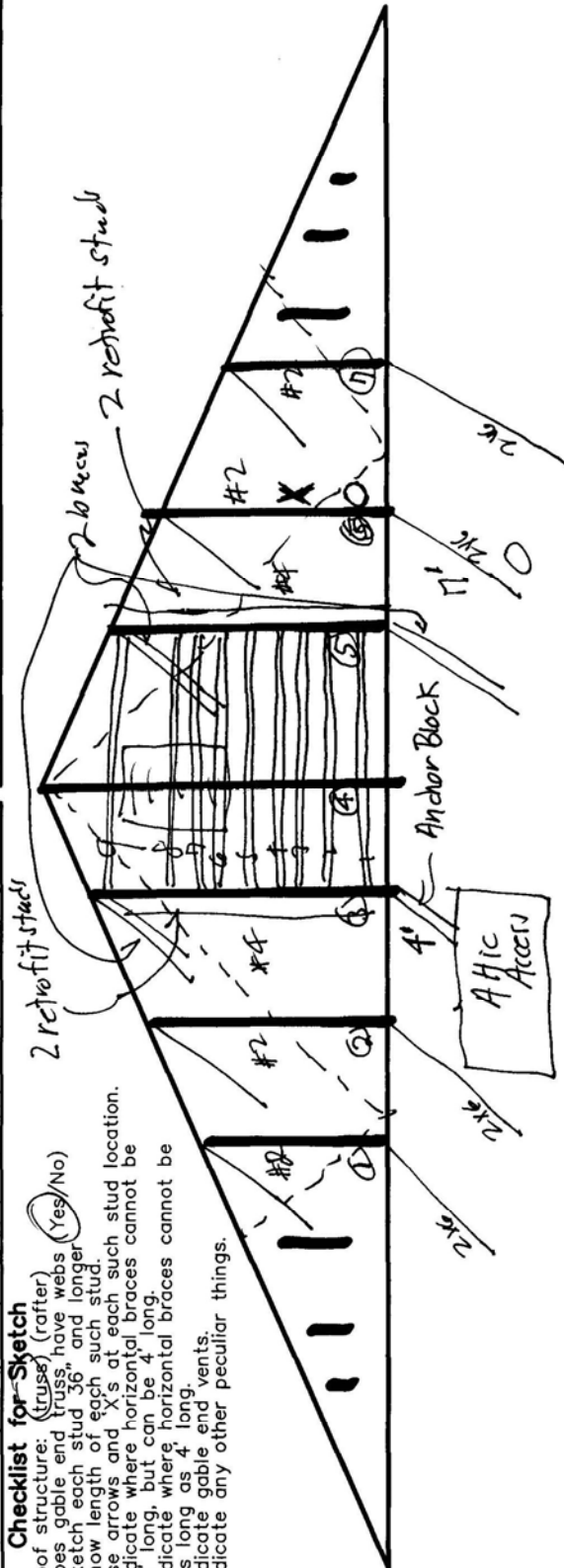
Sample Sketch Page

From Table 1									
Attic observations					From Table 1				
Stud Num.	Side	Retrofit stud length	Method #	# of Horiz. Braces	Retrofit Stud #1 2x4	#2 2x6	#3 2x8	#4 2-2x8	Strap Length
13	Left								
14	Right								
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
Totals ->									

From Table 1									
Attic observations					From Table 1				
Stud Num.	Side	Retrofit stud length	Method #	# of Horiz. Braces	Retrofit Stud #1 2x4	#2 2x6	#3 2x8	#4 2-2x8	Strap Length
1	LR	4'-7"	2	2					36 9 14"
2	LR	6'-7"	2	2					36 9 14"
3	LR	8'-7"	4	4					36 8 12" 12
4	Gable end vent								
5	LR	8'-6"	4	4					36 8 12" 12
6	L	6'-8"	2	2					34 9 14" 8
7	LR	4'-8"	2	2					36 9 14" 8
8									
9									
10									
11									
12									
Totals ->									

Checklist for Sketch

1. Roof structure: (trusses) (rafter)
2. Does gable end truss have webs (Yes/No)
3. Sketch each stud 36" and longer
4. Show length of each such stud
5. Use arrows and X's at each stud location.
6. Indicate where horizontal braces cannot be 6' long, but can be 4' long.
7. Indicate where horizontal braces cannot be as long as 4' long.
8. Indicate gable end vents.
9. Indicate any other peculiar things.



Reminders
All methods have to be increased because of webs

Appendix A

Engineering Drawings showing Gable End Retrofit Components and Connections

